September/mid-October (although some personal sampling results were reported that exceeded PEL levels on widely-scattered days from late October into early 2002 for the WTC 5 Building area at Ground Zero). Nor were there any notable blood lead elevations (maximum values < 20 μg/dl) among more than 300 male fire fighters serving at WTC Ground Zero and sampled by CDC in October 2001 (personal communication, P. Edelman). These data tend to suggest that, although it can not be entirely ruled out, it is unlikely that any pregnant or other women of childbearing age working within the WTC Ground Zero perimeter (e.g., among rescue/recovery personnel or assisting with dispensing of food, beverages or other aid to such personnel) would have experienced sufficient lead exposures to be at high risk for lead intoxication effects on them or any fetuses in-utero during or soon after WTC-related lead exposures.

It should also be noted that limited lead results available for analyses of bulk dust samples taken at locations close to the WTC did not appear to show any notably high lead concentrations. The values for bulk dust samples near the WTC noted in the WTC trends report ranged from 120 to 370 μg/g (ppm) - the latter value for a sample taken at Park Place and West Broadway on September 16. These values are consistent with lead concentrations found by ORD in bulk dust near the WTC (median 142 ppm) or those reported by cooperating academic investigators (Lioy et al., 2002) as ranging from 101 to 625 μg/g in bulk dust collected several blocks east of the WTC within days after September 11. They are also not exceptional in comparison with the 500 - 1000 ppm street dust or residential soil lead concentrations often still found in U.S. urban areas in the 1990s, as earlier stated. However, as Lioy noted, indoor exposures to lead-contaminated WTC-derived dust that penetrated indoors could continue to pose risks to individuals re-occupying buildings not cleaned by effective decontamination procedures.

On the basis of results evaluated to date, there is little indication of any substantial health risks being associated with lead exposures of the general population in lower Manhattan areas around the WTC site. However, evaluation of blood lead levels and pertinent medical records for any pregnant women exposed at Ground Zero or in its immediate vicinity during September or early October could provide useful further data by which to assess any such possible health risks associated with WTC-generated lead emissions.

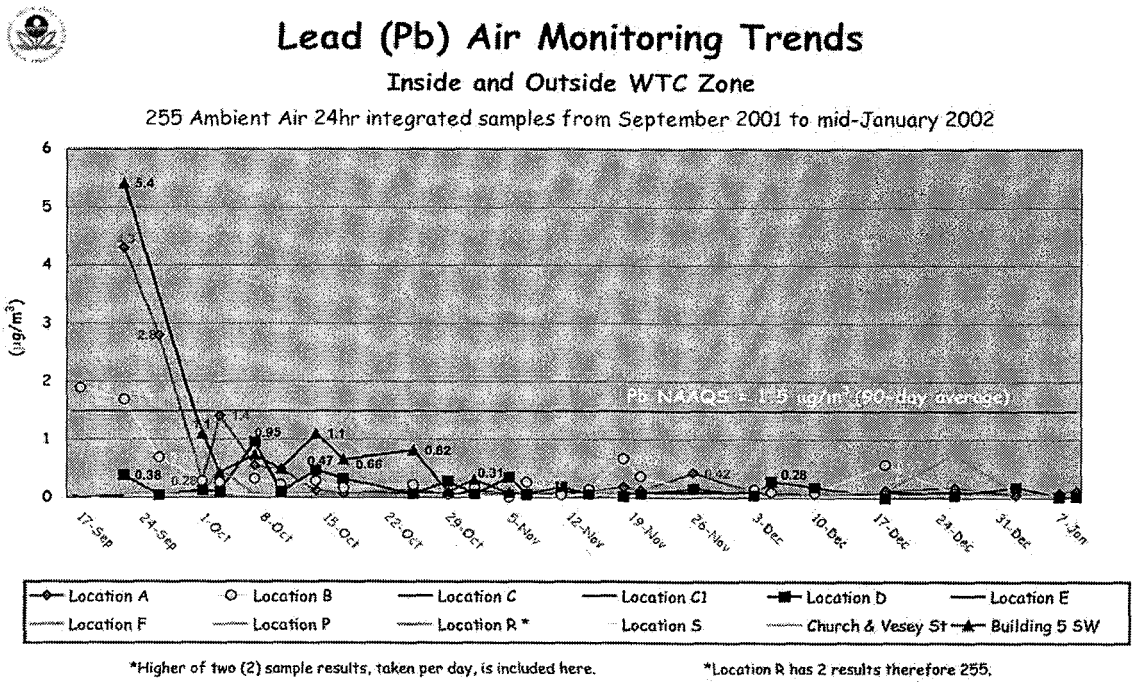


Figure 20. Ambient air lead concentrations ($\mu g/m^3$) at sites within Ground Zero or in lower Manhattan locations in immediate vicinity of the WTC.

Source: EPA Region 2

IV.b.2. Chromium and Nickel

Chromium and nickel were chosen for evaluation in this assessment because both can be irritating and sensitizing. Chromium and nickel are used in the production of stainless steel and other metal alloys. Chromium, in the hexavalent form, Cr^{+6}, can damage the nose and cause cancer. Similarly, workers who have breathed large amounts of nickel have developed lung and nasal sinus cancers. Total chromium in urban air typically ranges from 0.01 to 0.03 $\mu g/m^3$ (ATSDR, 2000c), and nickel concentrations in urban air range from 0.001 to 0.328 $\mu g/m^3$ (ATSDR, 1997b).

To evaluate chromium and nickel, the OSHA PELs (chromium, 1 mg/m^3; nickel, 1 mg/m^3) were used as a screening benchmark (NIOSH, 2002). For chromium, the ATSDR intermediate inhalation MRL for Cr^{+6} PM (1.0 $\mu g/m^3$) was also used (ATSDR, 2000c). For this evaluation, it was assumed that chromium would be released as solid PM, not as a mist, in order to compare measurements with the ATSDR MRL, which is specific to PM concentrations.

Data for evaluating chromium and nickel came mostly from the EPA WTC monitoring database. A total of 21 air samples, collected between September 23 and January 31 at Building 5, were evaluated for chromium and nickel at Ground Zero. None of the samples evaluated exceeded a screening benchmark for either chromium or nickel, nor did any values detected by ORD monitoring on the Ground Zero perimeter (Figure 18) exceed any benchmark values for chromium or nickel. On the basis of the results reported, chromium and nickel releases would not have been expected to cause any adverse health effects within Ground Zero.

Approximately 512 monitoring samples collected at sites surrounding Ground Zero were evaluated for chromium, including 86 samples taken at the Staten Island landfill and 16 samples from personal air monitors worn by NYC fire department personnel. Approximately 637 monitoring samples collected at sites surrounding Ground Zero were evaluated for nickel, including 86 samples taken at the Staten Island landfill. Samples were collected between September 23 and January 31. None of the samples evaluated for either chromium or nickel exceeded a screening benchmark. On the basis of the samples collected, chromium and nickel releases would not have been expected to cause any adverse health effects at sites surrounding Ground Zero.

Like most contaminants, however, elevations in chromium were seen in concentrations measured near Ground Zero, and near September 11 in time. At the Ground Zero monitoring, WTC building 5, chromium was not detected in four samples from September 23 to October 8, but then it was detected at 0.24 and 0.38 $\mu g/m^3$ on October 11 and October 15. Further sampling at Ground Zero through February of 2002 showed mostly non-detects (9 samples) and samples near typical background for chromium (4 samples between 0.02 and 0.07 $\mu g/m^3$), except for one higher reading at 0.22 $\mu g/m^3$ in January, 2002. Chromium sampling at all other sites around Ground Zero showed the same trend: elevations above typical urban background through about mid-October, with measurements then dropping to typical urban background (with a spike in January, which may or may not be due to Ground Zero emissions) through the sampling in February of 2002.

Unlike chromium, nickel was not found elevated above background at any time or location

in sampling. Measurements were mostly non-detects in within Ground Zero and in all locations measuring nickel, with sporadic measurements all less 0.1 $\mu g/m^3$.

IV.c. Polychlorinated Biphenyls (PCBs)

PCBs are a group of synthetic organic chemicals potentially composed of 209 individual chlorinated biphenyl compounds (known as congeners). PCBs were manufactured as mixtures of individual compounds having 1 to 10 chlorine atoms on the molecule. Being relatively stable compounds, their high boiling points and resistance to breakdown by high temperatures made them useful in a broad array of industrial applications. Furthermore, as PCBs do not conduct electric current, they were useful for commercial purposes as insulating material and electrical dielectric fluid in transformers and capacitors.

In 1971, Monsanto Corporation, the major U.S. producer, voluntarily restricted the sales of PCBs to uses as dielectric fluids in "closed electrical systems." This restriction was prompted by growing evidence of PCBs' persistence in the environment, their tendency to bioaccumulate in animal tissues, and their toxic effects, namely as probable human carcinogens. Monsanto ceased PCB manufacture in mid-1977 and shipped the last inventory in October 1977 (Erickson, 1997). Regulations issued by EPA beginning in 1977, principally under the Toxic Substances Control Act (40 CFR 761), have strictly limited the production, import, use, and disposal of PCBs.

Because the WTC was built in the early 1970s, it can be surmised that PCBs may have been present or contained in transformers, capacitors, electrical insulating and cooling applications, fire-resistant coatings to building materials, and electrical fluorescent lighting fixtures. As a consequence of the collapse of the WTC towers, many of these materials were pulverized, ruptured, or burned, which caused PCBs to be released into the surrounding environment. Additionally, PCBs were likely entrained within the smoke plume that emanated from the debris piles at Ground Zero. The primary focus of this section is to evaluate the potential human health risks that may be associated with inhalation exposure to the variable air concentrations of PCBs measured in lower Manhattan in the aftermath of the disaster.

IV.c.1. Air Monitoring for PCBs

PCBs were monitored at 12 different sites around Ground Zero and in other areas of lower Manhattan. Several hundred ambient air samples were collected between September 16, 2001, and April 24, 2002. One-day samples were taken using a high-volume polyurethane foam (PUF) and glass fiber filter (GFF) sampler. The GFF is used to collect and retain PCB- contaminated particles that may be present in the air, whereas the PUF material is used to capture any gaseous form of PCBs. In this monitoring program, only the sum of the PCB congeners present in air was quantified. Figure 21 displays the locations of the PCB air monitoring stations in lower Manhattan.

The primary source of PCB monitoring data used in this analysis was the publicly accessible information posted on EPA's WTC web site (http://www.epa.gov/wtc). This information is current through April 24, 2002. Table 3 presents a summary of the ambient air sampling results for PCBs in and near the WTC disaster site.

To put these measurements into perspective, background levels of total PCBs in air at urban locations in the U.S. are typically in the range of 1 to 8 ng/m^3 (ATSDR, 2000a). Slightly elevated air concentrations were found up to 1 month after September 11 only at the Ground

Zero site, WTC Building 5 SW. The highest one-day PCB air measurement of 153 ng/m^3 occurred on October 2, 2001. This level is approximately three-fold higher than the next two PCB levels observed at WTC Building 5 on September 16 and October 4: 55.9 and 58.6 ng/m^3, respectively. By November 2, PCB levels at this site had further decreased to 18 ng/m^3. Measurements from November 6, 2001 to April 24, 2002 showed that total PCB levels in air decreased to below the limits of detection. Barclay and West Broadway registered the next highest one-day PCB air concentration at 77 ng/m^3 on October 4. This monitor bordered a restricted zone, but could represent a concentration in an area just above the corner of Barclay and West Broadway that was unrestricted after September 19. This October 4 measurement was about nine times greater than the measurement taken October 2 at this site (8.3 ng/m^3), and approximately ten times higher than typical urban background air. By November 2, PCB air levels had decreased to 9.7 ng/m^3. Following November 2, total PCB was not detected at Barclay and West Broadway until February 19, 2002, at which time a concentration of approximately 3 ng PCB/m^3 was detected. From February 24, 2002, through April 24, 2002, PCB levels dropped below the limit of detection. Because the limits of detection were within the range of typical urban air measurements, it can be concluded that PCBs had dropped to and remained within this range of typical urban air concentrations after November 8.

To summarize, elevations above the typical background range of 1 - 8 ng/m^3 were only seen in the initial month after 9/11, and only within Ground Zero and the border sampling location of Barclay and West Broadway. All monitoring sites to the west of Ground Zero showed no elevation above background PCB concentrations at any time in the month following the disaster. By November 8, PCB levels in air were within the range of expected urban background air at all monitoring locations, including Ground Zero.

IV.c.3. Potential Human Health Consequences of Exposure to PCBs in Air

Different approaches are used here to assess potential health effects of exposure to PCBs at or near the WTC site. First, EPA's procedure for estimating cancer risk is used. Then, comparison of air concentrations to benchmarks published by ATSDR, NIOSH, and OSHA are conducted.

EPA currently classifies PCBs as B2 carcinogens; a probable human carcinogen (IRIS, 2002). The basis for this classification stems largely from long-term animal studies supplemented with human studies. A 1996 study found liver tumors in female rats exposed to Aroclors1260, 1254, 1242, and 1016, and in male rats exposed to 1260. These mixtures contain overlapping groups of congeners that, together, span the range of congeners most often found in environmental mixtures. Earlier studies found high, statistically significant incidences of liver tumors in rats ingesting Aroclor 1260 or Clophen A 60 (Kimbrough et al., 1975; Norback and Weltman, 1985; Schaeffer et al., 1984). Mechanistic studies are beginning to identify several congeners that have dioxin-like activity and may promote tumors by different modes of action.

PCBs are absorbed through ingestion, inhalation, and dermal exposure, after which they are transported similarly through the circulatory system. This pattern provides a reasonable basis for expecting similar internal effects from different routes of environmental exposure. Information on relative absorption rates suggests that differences in toxicity across exposure routes are small. The human studies are being updated; currently available evidence is

inadequate, but suggestive of PCB carcinogenicity.

From the dose-response data derived from animal studies, the EPA has calculated an upper bound cancer slope factor of $1*10^{-4}$ $[\mu g/m^3]^{-1}$ associated with continuous lifetime inhalation exposure to PCBs. This slope factor pertains to exposure to total PCBs, which may or may not contain dioxin-like PCBs. For exposure to dioxin-like PCB congeners alone, the slope factor developed for dioxin-like compounds should be applied (EPA, 2000a). This assessment does not consider exposure and risk from dioxin-like PCBs because these congeners were not measured separately. The Toxic Equivalent (TEQ) concentrations discussed in the dioxin section below are specific to dioxin and furan congeners only.

A cancer risk from a less-than-lifetime inhalation exposure to total PCBs is given as:

$$\text{Risk} = \text{LAC} * \text{UR} \qquad (2)$$

where LAC is the air concentration averaged over a lifetime, calculated as: AC * [ED/LT], where AC is the average air concentration during the period of exposure ($\mu g/m^3$), ED is the exposure duration (days), LT is lifetime (days), typically 70 years, and UR is the unit risk factor, expressed in units of 1/concentration.

In order to conduct a simple screening exercise to evaluate the cancer risk from inhalation of elevated levels of PCBs near the WTC site, a representative air concentration and a time during which exposure to that concentration occurred need to be determined. The areas in which PCB air concentrations were elevated were generally located within the "restricted zone". Still, even if an individual were exposed to the highest concentration found at 153 ng PCB/m^3 for a period of 1 month (and all the data suggests that elevations did not exist beyond 1 month), the lifetime cancer risk would be estimated at about $2*10^{-8}$ (calculated as: [0.153 $\mu g/m^3$] * [30 days/ (70 years*365 d/yr)] * [$1*10^{-4}$ $(\mu g/m^3)^{-1}$]). EPA regulatory programs, such as the Superfund Program, typically consider individual incremental cancer risk estimates made in this manner (i.e., in the context of a scenario-based risk assessment) in the range of 10^{-4} to 10^{-6} to be of potential significance, depending on the circumstances. On this basis, an incremental cancer risk estimate in the range of 10^{-8} is judged to be insignificant.

ATSDR has published a Toxicological Profile for PCBs (ATSDR, 2000a). This Toxicological Profile is a comprehensive review and summary of existing health effects information relevant to human exposures. From this review, it is concluded that all the measured PCB levels in air in or around the WTC site were well below the levels of significant exposure to PCB mixtures that were found not to cause adverse effects in experimental animals as a consequence of short-term inhalation exposure. These no-observed-adverse-effect-levels (NOAELs) in experimental animals ranged from 1.5×10^6 ng/m^3 for renal effects to 9×10^3 ng/m^3 for hepatic effects. These NOAELs are one to six orders of magnitude higher than the highest PCB air levels measured in Lower Manhattan.

Occupational exposure limits provide an additional perspective by which to evaluate potential non-cancer health effects that may be associated with inhalation exposure to PCBs measured in the air at or near the WTC site. NIOSH publishes RELs and OSHA publishes PELs

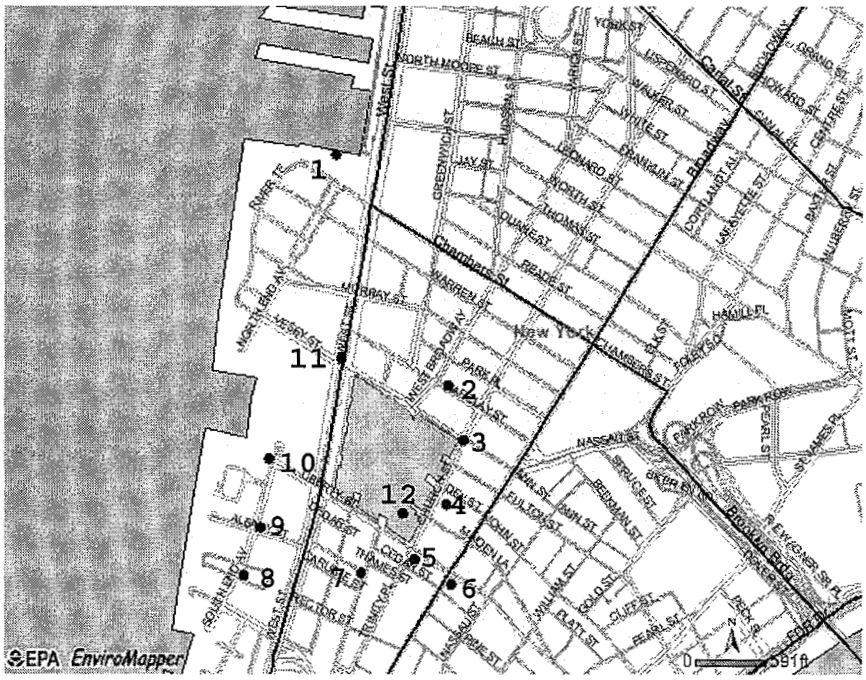
for occupational exposures to chemical contaminants. The NIOSH REL is 1 x 10^3 ng/m^3 as an 8-hr TWA air concentration (NIOSH, 2002). The REL is associated with long-term or repeated exposures and is protective of effects on the liver and the reproductive system. All PCB air measurements at or near the WTC site have been below the NIOSH REL. The OSHA PEL is 5 x 10^5 ng/m^3 as an 8-hr TWA air concentration (NIOSH, 2002). The PEL is associated with long-term or repeated exposures and is protective of effects on the skin (dermatitis). All PCB air measurements at or near the WTC site have been below the OSHA PEL.

Table 3. Summary of PCB monitoring data between September, 2001, and April, 2002.

Location	Sampling Date	Concentration ng PCB/m^3 air	Sampling Date	Concentration ng PCB/m^3 air
Albany & Greenwich	9/16 - 10/4; 7 samples	ND	11/02-12/11; 10 samples	ND
	10/8	9.2	12/19/01	2.2
	10/11 - 10/26; 4 samples	ND	12/27 - 4/24; 29 samples	ND
	10/30/01	1.8		
Albany & South End	9/16 - 4/24/; 53 samples	ND		
Barclay & West Broadway	9/16/01 & 9/23/01	ND	10/15 - 10/30; 4 samples	ND
	9/27	38.7	11/02	
	10/2	8.3	11/8 - 2/14; 23 samples	ND
	10/4	77.0	2/19	3.2
	10/8	ND	2/21 - 4/24; 15 samples	ND
	10/11	25.0		
Church & Dey	9/16	7.0	10/8	4.5
	9/23	4.0	10/11	2.2
	9/27	5.0	10/15 - 10/26; 3 samples	ND
	10/2	17.9	11/02	3.3
	10/4	13.3	11/8 - 4/24; 39 samples	ND
Church & Vesey	11/15 - 11/27; 4 samples	ND	12/11	1.4
	12/4	1.7	12/19 - 4/24; 30 samples	ND
	12/6	ND		
EPA TAGA Lab	9/11 - 4/24; 54 samples	ND		
Liberty & Trinity	9/16	8.1	9/23 - 4/24; 52 samples	ND
Liberty & Broadway	9/23 - 9/28; 3 samples	ND	10/8	16
	10/2	8.2	10/11 - 10/26; 4 samples	ND
	10/4	ND		
Rector & South End	9/16 - 4/11; 51 samples	ND		

Table 3. Summary of PCB monitoring data between September, 2001, and April, 2002 (cont'd).

Location	Sampling Date	Concentration ng PCB/m^3 air	Sampling Date	Concentration ng PCB/m^3 air
Vesey & West	9/16 & 9/27	ND		
Liberty & South End	9/23 - 5/28; 67 samples	ND		
WTC Building 5 SW	9/16	55.9	10/15	16.0
	10/2	153.0	10/18	5.7
	10/4	58.6	10/26	6.8
	10/8	18.1	11/2	18.2
	10/11	28.2	11/6 - 4/24; 38 samples	ND



KEY

(1) EPA Taga Lab

(2) Barclay & West Broadway

(3) Church & Vesey

(4) Church & Dey

(5) Liberty & Trinity

(6) Liberty & Broadway

(7) Liberty & Greenwich

(8) Rector & South End

(9) Albany & South End

(10) Liberty & South End

(11) Vesey & West

(11) WTC Building 5 SW

Figure 21. Location of PCB monitoring stations.

IV.d. Dioxin

Dioxin-like compounds (referred to also in discussions below simply as "dioxins") are formed during combustion, and it is expected that production of these compounds would have resulted from the initial impact and ensuing fires at the WTC. Dioxin-like compounds may be formed in other ways as well, such as in the chlorine bleaching process for paper products or in the manufacturing process for certain chlorinated organic chemicals. However, uncontrolled or improperly controlled combustion appears to be the major source of new emissions (EPA, 2000). A total of 30 compounds are considered to be "dioxin-like": 7 polychlorinated dibenzo-p-dioxins (abbreviated dioxins), 10 polychlorinated dibenzofurans (furans), and 13 coplanar PCBs. These individual compounds are called "congeners." Measurements at the WTC included only the 17 polychlorinated dioxin and furan congeners, not the PCB congeners (total PCBs were measured, as discussed above). Because dioxin-like compounds are present at minute quantities, concentrations in this section will be described in terms of picograms per cubic meter (pg/m^3).

Concentrations of dioxin-like congeners are expressed on a toxic equivalent, or TEQ basis. A TEQ concentration is calculated as the sum of the toxically equivalent concentrations of each of the 17 congeners. A congener's TEQ concentration is calculated as its concentration (C_i) times its toxicity equivalency factor, or TEF_i. TEF values are equal to 1.0 or less, and relate the toxicity of 16 of the 17 congeners to the most toxic congener, 2,3,7,8-TCDD (the 17^{th} congener naturally assigned a TEF of 1.0). An overall TEQ concentration is, therefore, $\Sigma(TEF_i*C_i)$. When a congener was not detected in the sample, a value of one-half the detection limit was used for that congener in calculating the TEQ concentration. This is the traditional approach to calculating a TEQ concentration when some of the congeners are not detected and others are; alternate approaches include assigning either 0 or the detection limit to the congeners that are not detected.

The TEQ concentrations on the WTC web site were developed using the "International" set of TEF values (I-TEF; EPA, 1989). In 1998, the World Health Organization proposed a new set of TEF values (WHO-TEF; Van den Berg, 1998). The principal change relevant to quantifying the TEQ concentration of a mixture comprised of the 17 dioxin and furan congeners is that the TEF for the penta dioxin-like congener, 1,2,3,7,8-PCDD, has been increased from 0.5 to 1.0. The other change of less impact to calculating the TEQ concentration is that the TEF values of the two octa congeners, OCDD and OCDF, were reduced from 0.001 to 0.0001. Since the penta congener occurs in most samples, the net effect of this change is to increase the TEQ concentration slightly, in the range of 5-10%, depending on the prevalence of 1,2,3,7,8-PCDD in the sample. For example, on the sample taken from the WTC Building 5 monitor on September 23, when the I-TEQ concentration was 161 pg TEQ/m^3, the 1,2,3,7,8-PCDD concentration was 40.8 pg/m^3. In the I-TEF scheme, this contributes 20.4 pg/m^3, but in the WHO-TEF scheme, this would add 40.8 pg/m^3 to the final TEQ concentration. Therefore, the measurement of 161 pg TEQ/m^3 would increase to 181 pg TEQ/m^3 when switching to the WHO-TEF scheme, an increase of about 12%. An examination of the data shows that other I-TEQ concentrations would also increase, some by less than 5%.

This assessment uses the I-TEQ concentrations presented on the EPA WTC web site. Converting to WHO-TEQ concentrations would make a small and insignificant change to the

calculations presented in this section, would not result in changing any of the principal findings, and would possibly be confusing to those who notice a difference in the concentrations described here compared to those posted on the EPA web site.

Some of the major health risks associated with dioxin exposure include, but are not limited to, cancer and noncancer effects, including reproductive, developmental, and immunologic effects. A complete discussion of the health effects of exposure to dioxin-like compounds can be found in EPA's draft Dioxin Reassessment Document (EPA, 2000). This WTC report draws on procedures outlined in that document for conducting simple screening assessments relating to potential long-term cancer and noncancer effects from exposure to dioxin concentrations measured on and near the WTC site.

IV.d.1. Dioxin Air Monitoring Data

Figure 22 shows the location of 16 air monitoring sites at which dioxin measurements have been taken. Four of the sites had very few samples, so the focus in this section is on the 12 samplers that had a significant number of samples. At all sites, high-volume air samplers were used. Each sampler contained both a GFF and a PUF cartridge. The GFF is used to collect and retain particle-phase dioxins, whereas the PUF material is used to capture gas-phase dioxins. The GFFs and PUFs were sent to laboratories for measurement of the 17 dioxin-like congeners using EPA method SW8290.

Two different groups conducted the dioxin monitoring. Nine of the 12 sites measuring a significant number of dioxin samples were "lettered" sites managed by the EPA's Environmental Response Team (EPA ERT). These 9 sites sampled for 8 hours per sampling event. On the other hand, 3 of the 12 sites were "numbered" sites were established by the New York State Department of Environmental Conservation (NYSDEC), and they monitored for 72 hours per sampling event. For dioxin sampling, these 3 NYSDEC samplers were managed by EPA's Region 2 personnel, who sent the samples to EPA's Region 7 laboratory for analysis. For this reason, these will be referred to as the Region 2/7 monitors/samples.

The amount of time the monitor operates directly affects the amount of air that went through the monitors for dioxin collection: the Region 2/7 sampling captured dioxins contained in about 1000 m^3 of air (i.e., about this much air was drawn into the sampler over 72 hours), whereas the EPA ERT sampling captured dioxins in about 7 m^3 air. The majority of the EPA ERT samples simply did not contain enough mass of dioxins to be able to detect, much less quantify, the dioxin-like congeners in the sample. When the method cannot detect the congener in the sample, a result of "nondetect" (ND) is reported, and the detection limit (DL) is supplied. The method's detection limit is calculated by dividing the lowest amount of dioxin that it can detect (on the GFF and PUF) by the air that contained that amount, namely the air that flowed through the sampler. The greater the air flow, the greater the divisor for the unchanging detection amount, and the lower the detection limit. Except for the high concentrations measured within and near Ground Zero from September through late November, most of the samples taken by the EPA ERT samplers contained mostly non-detects. Therefore, TEQ concentrations ended up being calculated with all or most congeners set equal to a value of one-half the detection limit.

Calculating TEQ concentrations with most congeners assigned values of one-half detection limit is not an issue when a sufficient quantity of air is drawn into the monitor, and the inability to measure the dioxin in the sample truly does signify a very low amount of dioxin in the sample. For example, congeners in the Region 2/7 samples could be quantified if they were present at concentrations higher than about 0.5 pg/m^3 because enough air was drawn into the monitors leaving behind enough dioxin molecules on the monitor's filters. The congeners in the EPA ERT samples could not be quantified unless they were present at about 5-10 pg/m^3. When most of the congeners reported a non-detect in one of the Region 2/7 samples, the calculated TEQ concentration was in the range of 0.01 to 0.10 pg TEQ/m^3, whereas when most of the congeners were reported as non-detect in the EPA ERT samples, the calculated concentration ranged from 0.5 to 5.0 pg TEQ/m^3. As will be discussed below, typical urban air concentrations are in the range of 0.10 to 0.20 pg TEQ/m^3, and these measurements come out of studies where, like the Region 2/7 samples, a sufficiently large quantity of air was drawn into the monitors.

Assigning one-half detection limit for non-detects is typical and appropriate for evaluating exposure to airborne contaminants, dioxins or otherwise. In some circumstances, this practice can underestimate the amount of contaminant in the air - i.e., when the actual concentration is just below the detection limit and above the half-detection limit value. However, in this case, it is clear based on comparison with the Region 2/7 samples and from other historical measurements around the United States, that the practice of assigning one-half detection limit to non-detects in the EPA ERT samples resulted in an overestimate of the TEQ concentration when most of the congeners in the sample were non-detects.

For purposes of analysis in this section, a limited set of the dioxin data is used. Table 4 shows reported TEQ concentrations for the WTC Building 5 EPA ERT monitor, the Church & Dey EPA ERT monitor, and the Park Row Region 2/7 monitor. These values were calculated at ND = ½ DL; in parenthesis for the two EPA ERT monitors is the TEQ calculated at ND = 0. The WTC Building 5 monitor had the highest concentrations, and the Church & Dey monitor was in the predominant downwind direction for most monitoring events and had the second highest measurements. The Park Row monitor began operation on October 12 and had numerous measurements through March of 2002. Figure 22 shows the location of these three monitors. The following observations are based on the data in Table 4:

- The WTC and Church & Dey measurements from the first measurement day of September 23 through November 21 show unambiguous elevation, with concentrations ranging from about 10 to 170 pg TEQ/m^3.

- In this same time frame and for these two samplers, the influence of having high detection limits is seen in a few samples (WTC sample on 10/4: 176 pg TEQ/m^3 at ND = ½ DL versus 140 pg TEQ/m^3 at ND = 0; WTC sample on 10/11: 52.4 versus 9.6), but mostly, the congeners were detected and quantified, and TEQs were similar at ND = 0 and ND = ½ DL.

- The 6 Park Row measurements between October 12 and October 29 averaged 5.6 pg TEQ/m^3. These measurements are consistent with the mid- to late-October measurements at Church & Dey, which is slightly off-site from Ground Zero, of

10 to 20 pg TEQ/m^3. Further, the Church & Dey measurements of 10 - 20 pg TEQ/m^3 for mid to late October are consistent with the WTC measurements for that time period of 20 - 50 pg TEQ/m^3. In other words, the highest measurements are onsite (WTC); the next highest measurements are slightly offsite (Church & Dey), and slightly lower concentrations are farther offsite (Park Row). This is strong evidence that emissions from the WTC site are the cause for elevated air concentrations within and near the WTC site.

- The Park Row measurements from December 2001 through the last reported measurements of March 18, 2002, are less than 0.11 pg TEQ/m^3, and all the 2002 measurements are less than or equal to 0.05 pg TEQ/m^3. These values are consistent with those of the other two Region 2/7 samplers (see Figure 22). They are also consistent with typical urban concentrations of dioxin TEQs (see discussion after bullets), which leads one to believe that these concentrations might be representative of typical "background" New York conditions.

- The December through April measurements from the WTC Building 5 and Church & Dey monitors are nearly all non-detects. The reported concentrations average about 1.4 pg TEQ/m^3, but this is of limited interpretive value since the detection limits were too high. The actual concentrations could be more like the concentrations of about 0.05 pg TEQ/m^3 found at the Park Row sampler, but it is not possible to conclude that since the data are not available.

Other measurements made in the United States and around the world can be used to put these measurements in perspective. As noted earlier, EPA's draft Dioxin Reassessment compiled urban and rural air monitoring studies and found average ambient concentrations of 0.12 pg TEQ/m^3 for urban and 0.017 pg TEQ/m^3 for rural settings. Higher concentrations have been identified in the literature, particularly near a known source of dioxin emissions. The highest TEQ concentration reported in the U.S. was > 1.0 pg/m^3, downwind of an incinerator in Niagara Falls, NY. Concentrations in the plume of a solid waste incinerator in Columbus, OH, that was known to be emitting large amounts of dioxins were about 0.25 pg TEQ/m^3. In this case, the stack was very tall (about 80 meters) and air measurements were taken about 2 kilometers away. Background air concentrations in Columbus were measured to be about 0.05 pg TEQ/m^3.

Air concentrations near an incinerator in Japan adjacent to a U.S. Naval Air Base were regularly measured on the base for dioxin-like compounds. Measurements at the nearest downwind monitor, at about 200 meters, averaged 3.5 pg TEQ/m^3 for weekly samples over a 15-month period. For five samplers (including the nearest downwind sampler) at various locations on the base up to 800 meters, the average air concentration was 1.6 pg TEQ/m^3. An examination of the air concentration data on this base in conjunction with wind rose data, suggested that a background air concentration in this area was less than 0.5 pg TEQ/m^3 and that measurements above that were due to the influence of the incinerator (Walker, et al., 2002). Other measurements in cities in Japan have been in the 0.3 to 0.7 pg TEQ/m^3 range, and these are the highest that have been reported as typical air concentrations worldwide.

Although none of these literature measurements can be assumed to represent New York levels, they provide some basis for perspective. Certainly, no reports in the literature could be found on similar circumstance where there is, what is essentially, an area source at ground level continually emitting dioxins near to where individuals are exposed. It would be reasonable to conclude that the concentrations to which individuals could potentially be exposed, in the range 10.0 to 170.0 pg TEQ/m^3 within and near the WTC site found through the latter part of November, are likely the highest ambient concentrations that have ever been reported.

IV.d.2. Potential Human Health Consequences of Exposure to Dioxins in Air

The exposure of humans to dioxins is predominantly through the food supply; about 95% of exposure is through consumption of animal food products. Inhalation exposure and absorption via the skin are generally minor pathways for the average U.S. citizen (i.e., the background population). EPA has estimated that about 4% of the background human dose of dioxin is due to inhalation, based on an average urban level of 0.12 pg TEQ/m^3 and an inhalation rate of 13.3 m^3/day. If the concentration of dioxin in the air is increased, the amount of exposure due to inhalation would be increased, but the total amount of dioxins contributed by the inhalation pathway might still be small in comparison to the contribution made by food ingestion.

In the WTC situation, elevated dioxin concentrations in the air can be expected to increase the proportion and extent of human exposure via inhalation and possibly skin contact routes for those people residing or working close to the WTC location. The extent to which these elevated atmospheric levels will translate into increased human doses depends on an individual's pattern of exposure, considering, for example, his or her location in relation to the WTC and downwind areas; the duration and time period of exposure such as workshift and return to residence patterns, movement and activity patterns during the time of elevated atmospheric levels; and whether respiratory protection devices were used. Dioxin-like compounds exist substantially in the atmosphere attached to particles, and these devices would remove a substantial portion of the dioxins through the removal of particulates; if these respirators contained a carbon filter, a substantial portion of the dioxins in vapor phase would also be removed.

This section will use the data shown in Table 4 to conduct cancer and non-cancer assessments of an individual's inhalation exposure to dioxins. The procedures used are described in detail in the draft Dioxin Reassessment (EPA, 2000; available at, http://www.epa.gov/ncea/dioxin.htm), with further references supplied below as necessary.

1. Daily Inhalation Doses

Cancer and non-cancer assessments entail the development of a "dose" term, which in this case is the dose received via inhalation. Inhalation dose estimates require assumptions about the hourly rate of inhalation (m^3/hr), the number of hours per day a person inhales at the site where he or she could be exposed (which could obviously be less than 24 hours if the individual does not live in the vicinity where air concentrations measurements were taken), the time period during which this exposure occurs, and, of course, the air concentration to which the individual is exposed.

Daily inhalation exposure dose is given by:

$$DD = [IN * HRD * C * ABS]/[BW] \quad (3)$$

where DD is daily dose (pg TEQ/kg-day); IN is the inhalation rate (m^3/hr), HRD is the hours/day of inhalation, C is the concentration (pg TEQ/m^3), ABS is the fraction of contaminant inhaled which is absorbed (unitless), and BW is the body weight (kg). The draft Dioxin Reassessment assumes an adult body weight of 70 kg and an absorption fraction of 0.8 for TEQ exposures, both from inhalation and food consumption, and these assumptions are used here. The average daily dose (ADD) is calculated simply as the average of the daily doses over the period of exposure.

2. Exposure Scenarios

The scenarios which were evaluated here include:

1) WTC worker: This individual was exposed 10 hours per day, 5 days per week, in the time period between September 12 and November 30, 2001. This time frame roughly corresponds to the time when it seemed clear that dioxin air levels were elevated according to the monitoring data. Measurements from the WTC Building 5 monitor represent the concentration to which this individual is exposed. A time-weighted average (TWA) air concentration was derived for this period. The air concentration between September 12 and September 23 (the date of the first measurement at the WTC monitor) is assumed to be equal to the September 23 measurement, and the concentration between November 8 (the last date in November for the WTC monitor) and November 30 was similarly assumed to be equal to the measurement on November 8. These seem to be reasonable assumptions since the September 23 measurement from the WTC monitor was the second highest found at 161 pg TEQ/m^3, and the November 8 measurement of 5 pg TEQ/m^3 reasonably reflects the downward trend of measurements at the site. Between September 12 and November 30, a TWA air concentration was derived to represent the concentration to which the workers were exposed. A TWA concentration is not the same as the simple average of concentrations measured. To derive the time-weighted concentration, concentrations were assigned to each day between September 12 and November 30. From one measurement to the next, air concentrations were assumed to linearly rise or fall. For example, if the concentration was measured as 100 pg TEQ/m^3 on one day and 5 days later it was 50 pg TEQ/m^3, the concentrations assigned to the intervening days were 90, 80, 70, and 60 pg TEQ/m^3. The TWA concentration is then simply the average of all the concentrations assigned to days when the worker was assumed to be exposed. With these assumptions, the average TEQ concentration during this time was calculated as 60.7 pg/m^3. The rate of inhalation for a WTC worker was 1.3 m^3/hr. This is equivalent to the rate for a "laborer" as quantified in EPA's Exposure Factors Handbook (EPA, 1997).

2) Office worker: This individual is exposed 10 hours per day, 5 days per week, and the exposure began on September 19, corresponding to the time when individuals were allowed back into office buildings outside of the Ground Zero site itself but in areas initially "restricted" near Ground Zero. The office worker was assumed to be exposed to air concentrations measured by the Park Row monitor. This simplistically assumes that the air concentrations within office buildings near Ground Zero were similar to air concentrations outside of office buildings this close to Ground Zero. The period of exposure was September 19 to November 30, and the same strategy to derive TWA concentrations was used as for the WTC worker. The TEQ air

concentration from September 19 to October 12 was assumed to be 8.4 pg/m^3, the measurement on October 12 at the Park Row monitor, and the TWA concentration between September 19 and November 30 was 4.8 pg TEQ/m^3. The rate of inhalation for an office worker was assumed to be the average inhalation rate of 1.0 m^3/hr, which is defined as "light activity" in EPA's Exposure Factors Handbook (EPA, 1997).

3) Resident: This individual was exposed 24 hours per day, 7 days per week, and the exposure began on September 19 and ended on November 30. As with the office worker scenario, the assumption here again was that individuals living near Ground Zero, in the vicinity of the Park Row monitor, were more exposed after September 19, when some of the locations outside of Ground Zero opened up to workers and residents. The daily inhalation rate was 0.55 m^3/hr, an average daily rate, activity unspecified, as developed in EPA's Exposure Factors Handbook (EPA, 1997). As noted, the air monitor used to characterize the air concentration was the Park Row monitor, which was located in an area not restricted after September 19. The average TEQ concentration during this time was 4.8 pg/m^3, as noted above.

3. Procedure for Cancer Risk Estimation

These assumptions and the resulting ADDs are shown in Table 5. Cancer risk were estimated simply as:

$$LADD = ADD * [ED/LT] \quad (4a)$$

$$Risk = LADD * SF \quad (4b)$$

where LADD is the lifetime daily dose (pg TEQ/kg-day), Risk is the upper bound incremental excess lifetime cancer risk that results from the exposure described by LADD, ADD is the average daily dose during the period of exposure (pg TEQ/kg-day), ED is the exposure duration (days), and LT is lifetime (days), typically 70 years, and SF is the upper bound cancer slope factor, expressed in inverse units to LADD, or [pg TEQ/kg-day]$^{-1}$. The SF of .000156 [pg/kg-day]$^{-1}$ was developed by EPA in 1984 for 2,3,7,8-TCDD exposures (EPA, 1984). It is applied to TEQ exposures in this cancer risk screening exercise. The draft Dioxin Reassessment (EPA, 2000) proposed an SF of 0.001 [pg/kg-day]$^{-1}$, which applies to dioxin TEQ exposures.

4. Procedure for Non-Cancer Risk Estimation

For noncancer risk, a different approach was taken. The best indicator of exposure for persistent, bioaccumulative, toxic substances such as dioxin is the concentration of the chemical in the organ or tissue of concern. A common metric for dioxin exposure is the "body burden", which is defined as the concentration of dioxins in the body, typically on a whole-weight basis. Body burden in this screening assessment is expressed on a lipid basis. It is assumed that adults are 25% lipid by weight, so that a lipid-based concentration can easily be converted to a whole-weight-based concentration by multiplying by 0.25.

Dioxins build up and decline over prolonged periods of time, since the overall biological half-life (the time for half the chemical to dissipate by either biological degradation or elimination) of dioxins in the human body is approximately 7 years. The use of the body burden as the measure of dose has implications for short-term exposures, such as those near the WTC

site, where elevated exposure rates limited to a period of days or months contributed to a pool of dioxin already accumulated in the human body over a lifetime. The current estimated body burden of dioxin (including only the 17 dioxin and furan congeners, not the dioxin-like PCB congeners discussed above) in U.S. adults is approximately 18 pg TEQ per gram of body lipid (18 ppt TEQ lipid). This average was derived from data on older as well as younger adults. Because exposures were known to be higher in the past, the body burdens of younger adults will be lower than those of older adults. Another factor contributing to the variability seen in the entire population is dietary pattern; individuals whose diets are higher in animal fat will have higher body burdens.

The effects of dioxin in humans range from biochemical changes at or near background levels to potentially adverse effects of increasing severity as body burdens increase above background levels. The "margin of exposure", MOE, can be defined as the ratio of body burden where effects are found divided by a body burden at a level of interest. The MOE for dioxin at current average body burdens (i.e., current average body burdens being the level of interest) is considerably less than that typically seen for environmental contaminants of toxicological concern. The potential contribution to health risks from specific dioxin sources or specific exposures, such as exposures from inhalation of air with elevated levels of dioxin, is best evaluated through calculating the incremental contribution of this source to the body burden.

The draft Dioxin Reassessment has assumed that a one-compartment, first-order pharmacokinetic (PK) model can be used to estimate the body burden that results from a specific intake regime. This simple PK model and its application to dioxin TEQs is also described in Lorber (2002). For an exposure of a finite time, the nonsteady-state form of this model to predict an increment in body burden (IBB) from a constant intake dose is given by:

$$IBB = [ADD/(k * LW)] * [1 - e^{-kt}] \quad (5)$$

where IBB is the increment of body burden on a lipid basis (pg/g, or ppt, lipid basis); ADD is the average daily dose (pg TEQ/day; not on a body weight basis), k is the first-order dissipation rate constant (1/day), LW is the weight of body lipids (g; equal to full body weight times 0.25, as described above), and t is the time of exposure (days). Use of Equation (5) with an average ADD over the period of exposure will provide an estimate of body burden at the end of the exposure. This is the time when the incremental body burden will be at its largest. In the scenarios of this assessment, different daily exposures result from different air concentrations as well as differences in exposure - 5-day work week followed by 2 days of non-exposure for the office worker scenario. Equation (5) is applied on a daily time step using Excel® spreadsheet procedures for this simple screening exercise.

A value of 17,500 g for the lipid weight (calculated as: 70 kg * 0.25 lipid fraction * 1000 g/kg), and a k of 0.000267 day^{-1} (= 0.098 yr^{-1}, corresponding to a 7.1 year half-life) will be used (Lorber, 2002). Results for this exercise include both an incremental body burden estimate, the IBB of Equation (5), calculated at the end of the exposure period, as well as a percent increase over background this represents. This percent increase is calculated as, [IBB/BK] * 100%. The BK is the background, which was assigned a value of 18 ppt TEQ lipid, as described above.

5. Results and Discussion

The exposure assumptions, the cancer risk estimates, and the incremental body burdens, are shown in Table 5. Before commenting on these results, it is important that they be put into perspective for general U.S. population dioxin TEQ exposures. As noted above, the background body burden of dioxin TEQs in adults is 18 ppt lipid. The draft Dioxin Reassessment estimates that the general adult population background TEQ exposure is 65 pg/day, or, expressed on a body-weight basis, 0.93 pg TEQ/kg-day. If this exposure is experienced over a lifetime, then the resulting incremental cancer risk from background TEQ exposure to the general adult population is equal to about $1.4*10^{-4}$ (assuming the 1984 SF of 0.000156 $[pg/kg\text{-}day]^{-1}$).

Table 5 shows that the TEQ ADD due only to inhalation during the period of exposure is 9 pg/kg-day for the WTC worker, 0.55 pg/kg-day for the office worker, and 0.73 pg/kg-day for the nearby resident. Although the WTC worker's daily exposure is higher than that of the general U.S. population, it is experienced for only a small number of days. Therefore, when averaged over a lifetime, the WTC worker dose calculates to an incremental cancer risk that is $3*10^{-6}$, which is about 2 orders of magnitude lower (100 times lower) than the U.S. background cancer risk from dioxin-like compounds ($1.4*10^{-4}$ as calculated above) . The office worker and resident experience incremental lifetime cancer risk at about $3*10^{-7}$, three orders of magnitude lower (1000 times lower) than background. EPA regulatory programs, such as the Superfund Program, typically consider individual incremental cancer risk estimates made in this manner (i.e., in the context of a scenario-based risk assessment) in the range of 10^{-4} to 10^{-6} to be of potential significance, depending on the circumstances. Exposure to dioxin-like compounds represents a unique circumstance, in that background exposures are already within this range and, in fact, at the upper end of this range. Therefore, although the upper bound incremental cancer risk to the WTC worker is estimated to be within the range of 10^{-4} to 10^{-6}, EPA judges these incremental cancer risks to be of minimal concern because they are 100 times and more lower than typical background exposures to dioxin-like compounds.

For noncancer risk, an increment of body burden, IBB, approach has been used. Table 5 shows that the exposure of the WTC worker suggests that his or her body burden could rise up to 10% above current average background, but that the nearby office worker and the residents have a rise of only 1% or less. EPA judges these incremental body burden increases to be of low significance, given the relatively high background exposures already experienced by the general population.

A key uncertainty remains as to the inhalation exposures that could be experienced by WTC rescue or clean-up workers, or nearby resident and office workers, who were in the area during the time period from about December onward. As discussed earlier, most of the samples had non-detects, but after assuming that the concentrations in the air were one-half the detection limit, all the measurements in 2002 from the EPA ERT samplers, which included the WTC Building 5 monitor, the Church & Dey monitor and many others, ranged from about 0.5 to 5.0 pg TEQ/m^3, which is about 5 to 50 times higher than normal background air concentrations. The three Region 2/7 samplers, the Park Row, Chambers St, and the Albany & West samplers, reported concentrations near 0.05 pg TEQ/m^3 from around December, 2001, through their last reported measurements in March, 2002. These were further away or generally upwind from the WTC site, so it cannot be assumed that they represent concentrations to which WTC workers and

others were exposed. Because the health risk from dioxin exposure is associated with accumulation of residues in body tissues, continued exposure throughout 2002 to dioxin, which was possibly elevated in the air, could not be evaluated. The risk screening exercises conducted for dioxin were limited to the time period when the concentrations were highest and dioxin was detected.

Table 4. Measured dioxin TEQ air concentrations at the WTC Building 5 monitor, the Church & Dey monitor, and the Park Row monitor (all units = pg TEQ/m^3; NR = not reported; all TEQ calculated at ND = ½ DL except values in parenthesis, which are calculated at ND = 0).

Date	WTC - Building 5	Date	Church & Dey	Date	Park Row
9/23	161.0 (161.0)	9/23	139.0 (139.0)	10/12[a]	8.35
9/27	NR	9/27	50.0 (NR)	10/14[a]	0.34
10/2	175.0 (170.0)	10/2	59.3 (57.2)	10/15[a]	4.78
10/4	176.0 (140.0)	10/4	51.9 (50.6)	10/16[a]	7.55
10/8	32.0 (28.7)	10/8	17.7 (15.5)	10/26	6.51
10/11	52.4 (9.6)	10/11	15.6 (11.8)	10/29	6.34
10/18	NR	10/18	9.6 (8.8)	11/1	3.05
10/26	28.1 (24.9)	10/26	11.4 (10.2)	11/5	1.54
11/2	26.8 (25.4)	11/2	16.1 (15.1)	11/8	0.27
11/6	0.3 (0)	11/6	0.1 (0)	11/12	1.33
11/8	5.6 (4.9)	11/8	7.6 (7.1)	11/15	1.33
11/12	NR	11/12	1.3 (0.6)	11/19	2.50
11/15[b]	5.4 (1.6)	11/15	3.4 (1.6)	11/22	1.30
11/21[b]	4.1 (3.1)	11/21	10.0 (8.3)	11/26	0.80
No samples reported from 11/21 to 1/15		11/27	2.5 (NR)	11/29	0.16
		12/4	0.7 (NR)	12/3	0.12
Jan 15 - April 24 n = 31 reported range: 0.4-5.5 average: 1.4 at ND = ½ DL and 0.0 at ND = 0.		12/6	0.2 (NR)	12/6	0.04
		12/11	0.2 (NR)	12/10	0.05
		12/19	0.6 (NR)	12/13	0.04
		12/27	0.3 (NR)	12/24	0.04
		Jan 3 - April 24 n = 29 reported range: 0.2 - 4.1 average: 1.4 at ND = ½ DL and 0.0 at ND = 0.		12/27	0.06
				12/31	0.11
				Jan - Feb n = 17 all samples reported < = 0.05	

[a] These Park Row samples were 24-hour samples; all other Park Row samples were 72 hour samples.
[b] These two World Trade Center samples were actually taken at the Church & Vesey sampler, which was sometimes used in place of the WTC Building 5 sampler.

Table 5. Human exposure and health risk assessment assumptions and results for dioxin TEQs.

Description	WTC worker	Office Worker	Resident
I. Exposure Assumptions and Results			
Inhalation rate, m^3/hr	1.3	1.0	0.55
Hours/day exposed	10	10	24
Days/week exposed	5	5	7
Air monitoring data used	WTC site	Park Row	Park Row
Period of exposure, dates/days	Sep 12- Nov 30, 57 working days	Sep 17 - Nov 30, 54 working days	Sep 12 - Nov 30, 79 days
Average TEQ air concentration, pg/m^3	61	4.8	4.8
Body weight, kg	70	70	70
Absorption, fraction	0.8	0.8	0.8
ADD, pg TEQ/kg-day	9.0	0.55	0.73
II. Cancer Risk Estimates			
Exposure Duration, yrs	0.16	0.15	0.22
LADD, pg TEQ/kg-day	$2.0*10^{-2}$	$1.2*10^{-3}$	$2.1*10^{-3}$
Cancer Risk	$3.1*10^{-6}$	$1.9*10^{-7}$	$3.6*10^{-7}$
Percent increase over $1.4*10^{-4}$ background risk	2.2 %	<1 %	<1 %
III. Body Burden Increases as a Measure of Potential NonCancer Risk			
Dissipation rate, 1/day	0.000267[1]	0.000267[1]	0.000267[1]
Change in body burden, pg TEQ/g lipid	+1.86	+0.14	+0.20
Percent increase over 18.0 pg TEQ/kg lipid background	10 %	<1 %	1 %

[1]This dissipation rate corresponds to a 7.1 year half-life in the body.

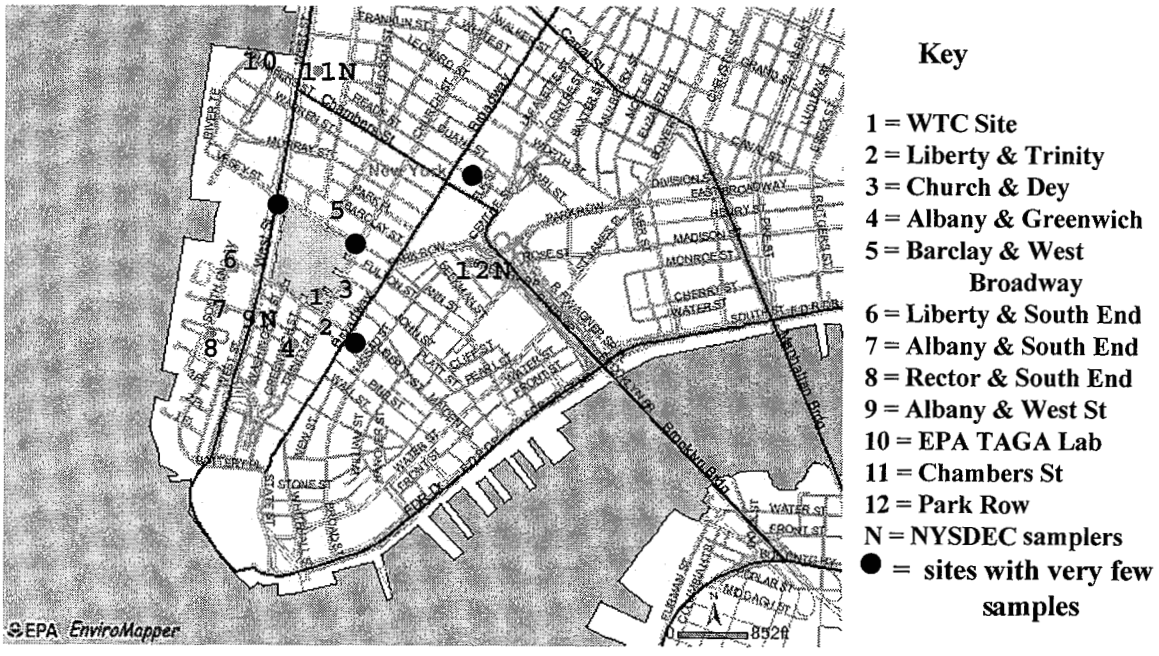


Figure 22. Location of dioxin air monitoring. The locations marked "N" are New York State Department of Environmental Conservation (NYSDEC) samplers maintained by EPA Region 2 with analysis of the samples by Region 7 (Region 2/7), whereas all other samplers are maintained by EPA's Environmental Response Team (EPA ERT). See text for discussion of the differences in the two sets of data from these two air monitoring teams.

IV.e. Asbestos

Asbestos is a term used to describe a family of hydrated metal silicate minerals. Asbestos exhibits some special properties, such as high tensile strength, the ability to be woven, heat stability, and resistance to attack by acid and alkali. Thus, it was widely used for building fireproofing insulation and other purposes during the 1960s and early 1970s. At the peak of its demand, about 3000 applications or types of products were listed for asbestos. In 1973, EPA prohibited the spraying of asbestos-containing material on buildings and structures for fireproofing and insulation purposes. The use of asbestos has been sharply declining for more than two decades. Sprayed on asbestos was used to fireproof approximately the lower half of one of the WTC towers, and may have been used in other places in the towers as well. One of the reasons that asbestos has been so useful is that it exists in long, thin fibers that can be sprayed, woven or mixed. The extremely light and aerodynamic asbestos fibers also lead to their ability to become and remain airborne. The fibrous nature also contributes to the health effects associated with asbestos exposure.

There are six minerals whose fibrous forms are characterized as asbestos and that are currently regulated. All the six minerals also occur in non-fibrous forms and these forms are not known to cause any health effects. The six regulated asbestos fibers include one from the serpentine family of minerals: chrysotile, and five from the amphibole family: fibrous reibeckite (crocidolite), fibrous grunerite (amosite), actinolite asbestos, anthophylite asbestos, and tremolite asbestos. Inhalation of these asbestos fibers has been linked to several adverse health effects including primarily fibrosis of the lungs (asbestosis), benign pleural plaques and thickening, lung cancer, and mesothelioma (a cancer of the thin membrane that surrounds the lungs and other internal organs). It also may increase the risk of cancer at other sites, but the evidence is not strong. Over the years the evidence has accumulated that longer thinner "asbestiform" fibers are of more concern for human health. The widely accepted definition of the asbestiform fiber is a particle having a length to diameter (aspect) ratio of $\geq 3:1$ and a length of at least ≥ 5 μm. The evidence is overwhelming that both the mineral content and the size and shape of the fiber affects the severity of the disease. The respirable fibers are those with the diameter of ≤ 3 μm. Fibers exceeding the diameter of 3 μm are considered to be non-respirable.

Asbestosis, a chronic, degenerative lung disease, has been documented among asbestos workers from a wide variety of industries. The disease is generally expected to be associated only with the higher levels of exposure commonly found in workplace settings (Brown et al., 1994; Case and Dufresne, 1997). Several researchers have found that asbestosis and lung cancer are associated with cumulative exposure to asbestos. Benign pleural plaques and thickening also have been linked to higher cumulative exposure to asbestos (Albin et al., 1996; de Klerk et al., 1993). Both asbestosis and benign pleural plaques result in reduced breathing capacity and mortality. In a review of the epidemiologic evidence for asbestosis exposure-response relationship, the World Health Organization Task Group on Environmental Criteria for Chrysotile Asbestos (WHO, 1998) concluded that "asbestotic changes are common following prolonged exposures of 5 to 20 f/mL." These prolonged exposures corresponded to cumulative exposure of 50 to 200 f/mL for a 10-year exposure period. They also concluded that "the risk at lower exposure levels is not known."

The majority of evidence indicates that lung cancer and mesothelioma are the most important risks associated with exposure to low levels of asbestos over a long period of time. There is ample evidence that all types of asbestos have been found to be associated with lung cancer. Several investigators have reported lung cancer mortality in workers exposed to chrysotile, amosite, crocidolite, anthophyllite, tremolite, and to multiple fiber types. The onset of exposure to time of occurrence of the disease is known as "latency period." As with most carcinogens, asbestos-related cancers have a substantially long latency period. The latency period for lung cancer has been reported to be 10 to 40 years. Most researchers have found that occurrence of lung cancer depends on the cumulative dose as well as other underlying lung cancer risk factors (U.S. EPA, 1986c; Peto et al., 1985). Similarly, several investigators have found that all types of asbestos cause mesothelioma of either pleura or peritoneum in adults who had occupational exposure. This finding also pertains to individuals who had no occupational exposure but who lived with a parent, spouse, or sibling who was an asbestos worker and presumably carried asbestos home on work clothes. Mesothelioma has a latency period of about 30 to 40 years. Lanphear and Buncher (1992) reviewed 1,105 mesothelioma cases in workers occupationally exposed to asbestos. They reported that 99% had a latency period >15 years and calculated a median latent period of 32 years. Further details on the toxicology and epidemiology of asbestos exposure can be found in the recent ATSDR Toxicological Profile for asbestos (ATSDR, 2001).

This next section reviews the air monitoring data for asbestos and discusses how these data relate to human health benchmarks developed for asbestos. The following sections discuss the analytical methods for measuring asbestos in air, the health risk benchmarks that measured air concentrations will be compared to, the background concentration of asbestos that can be compared to the measured values, and then the actual air data.

IV.e.1. Analytical Methods for Asbestos Ambient Air Measurements

The two analytical methods used in analyzing the WTC air samples for asbestos are phase contrast light microscopy (PCM) and transmission electron microscopy (TEM). PCM, although cheaper, is unable to distinguish between asbestos and nonasbestos fibers. It counts all fibrous structures with a minimum diameter of 0.3 μm and has a magnification range of 100 - 400X. Fibrous structures are defined as particles exhibiting a length of > 5 μm and an aspect ratio of length to width of 3:1. PCM cannot resolve internal structure or distinguish the mineralogy. PCM results are reported on a mass-per-volume basis, fiber per cubic centimeter (f/cc or f/cm^3) or, equivalently, fiber per milliliter (f/mL). TEM, on the other hand, is more expensive, but it can count the fibrous structures with a diameter of < 0.01 μm, and it can resolve internal structure and distinguish mineralogy. It has a magnification range of 5,000 - 20,000X. TEM results may be reported as concentrations or, for comparison with EPA AHERA standards (see below), as structures per square millimeter (S/mm^2) of filter in the ambient air monitor used. Details about the monitoring apparatus appropriate for measurement of asbestos using the TEM method and the appropriate ways to count and interpret the electron microscopy results are supplied in EPA (1987) and NIOSH (1994). Details about the PCM method for workplace measurements can be found in NIOSH (1994) and in OSHA (1994).

TEM data, expressed on a structures per filter unit area basis (as listed on the EPA web site), can be converted to a concentration in air in structures per cubic centimeter. This is

accomplished by multiplying the S/mm^2 term by a conversion factor defined as the area of the filter paper, mm^2, divided by the volume of air, liters or cubic centimeters, that is drawn into the air monitor. The AHERA Final Rule establishing a 70 S/mm^2 standard for asbestos in schools (EPA, 1987; see next section for more details on this benchmark), one of the standards used in this report to evaluate the WTC data, specifies that a volume at least 1199 L (liters; $1.199*10^6$ cc) must be drawn into a monitor with a 25 mm filter (this filter size corresponds to an effective area of 385 mm^2) or that a volume of at least 2799 L ($2.799*10^6$ cc) must be drawn into a monitor with a 37 mm filter (effective area of 855 mm^2) when applying the standard. Therefore, the conversion factors for both filters, to convert S/mm^2 to S/cc, are 0.000321 mm^2/cc for the 25 mm filter and 0.000305 mm^2/cc for the 37 mm filter. As a reasonable approximation, all results in S/mm^2 can be converted to a volumetric S/cc basis by multiplying by $3*10^{-4}$ [S/cc]/[S/mm^2], assuming 1200 L or 2800 L is drawn through an appropriate filter. Using this conversion factor, the AHERA standard of 70 S/mm^2 is equivalent to 0.021 S/cc.

However, the conversion to S/cc still does not put the data on an equal footing with PCM data expressed on a f/cc basis, because "fibers" are almost always different from "structures". Structures are bundles of fibers and many more "structures" can be identified by TEM than "fibers" by PCM because TEM can identify much smaller structures. Therefore, a TEM result for a given air sample (expressed on a volume basis, S/cc) will generally be greater than a PCM result for that same air sample (expressed as f/cc). In general there is not a good correlation between PCM and TEM measurements, and the ratios of the fiber counts seen with these two methods will vary according to the types of asbestos involved and the nature of the exposure setting. As noted below in making some rough comparisons, ATSDR has assumed a ratio of 60 of volumetric TEM data to volumetric PCM data; that is, PCM data was multiplied by 60 to convert the data to TEM units by ATSDR (ATSDR, 1999). The was done for the purpose of comparing different data from around the country to make observations about background asbestos concentrations.

As much of the health effects data on asbestos are expressed in terms of PCM f/cc, a useful variant of the TEM technique is to include counts of structures that would be expected to be visible under PCM and meet PCM criteria for counting as fibers. Specifically, structures meeting a minimum diameter of >0.3 μm with length >5 μm are counted as PCM equivalent ("PCME") fibers.

IV.e.2. Risk Assessment Benchmarks for Evaluation of Asbestos Air Data

The principal benchmark used in this assessment for evaluation of asbestos in air data from the WTC site is the Asbestos Hazard Emergency Response Action (AHERA) standard of 70 S/mm^2. This standard is determined by TEM analysis. This standard is described in the Final Rule and Notice for Asbestos-Containing Materials in Schools (40 CFR Part 763, October 30, 1987; cited in this report as EPA, 1987), and that rule also provides details on the monitoring apparatus and the structure counting procedure. This counting procedure includes discussions on the amount of filter area to examine with different volumes of air, and also the requirement to count fibers with an aspect ratio of $\geq$ 5:1 (aspect ratio = length to width ratio) and a length $\geq$ 0.5 μm. Briefly, this count of 70 S/mm^2 is specific to a minimum volume of air requirement (1200 L if the filter size is 25 mm, and 2800 L if the filter size is 37 mm), and with this volume, a reading

of 70 S/mm^2 was evaluated as being statistically distinguishable from the count that would come from a blank filter. That background count is about one-fourth the standard, or 17.5 S/mm^2. The AHERA rule specifies that children would be allowed back into a school that has been undergoing asbestos abatement (removal and/or encapsulation) if the TEM readings were consistently below the count of 70 S/mm^2. This would be evidence that the concentration was similar to background readings. Alternately, an abatement area could be deemed suitable for occupation if samples taken within the area were statistically similar to samples simultaneously taken outdoors in an asbestos-free environment. Details of these procedures are provided in the Final Rule, as cited above.

It should be noted that this standard is not health based, but rather technology based. It is also noted that the technology has improved since 1987, such that current filters often have much less than 17.5 S/mm^2, sometimes close to 0 S/mm^2. Therefore, 70 S/mm^2 would be much higher than blanks and represents more than just a statistical elevation above background. above. Finally it is noted that while the AHERA standard was originally intended as an indoor 'clearance' standard, it is being used to evaluate outdoor exposures in this assessment.

The current OSHA PEL is also used in this assessment to evaluate air concentrations of asbestos measured using the PCM method. The PEL for occupational exposures to asbestos is 0.1 f/cc by PCM averaged over an 8-hour day (OSHA, 1994). This standard is relevant for the comparison of exposure of rescue and other workers at the WTC site with current workplace standards. EPA also collected air samples analyzed for fibers by the PCM method that may be used for this purpose.

IV.e.3. Background Air Concentrations for Asbestos

ATSDR's Toxicological Profile for Asbestos (ATSDR, 1999) provides a summary of background asbestos levels. Because the health effects data regarding inhalation exposure to asbestos are usually expressed in terms of PCM f/cc, ATSDR chose to convert ambient air data reported in units of ng/m^3 or TEM f/cc to units of PCM f/cc. ATSDR's summary included these crude assumptions: 1 PCM f/cc is equal to 60 TEM f/cc and also approximately equivalent to a mass concentration of 30,000 ng/m^3. (Note, however, that there was not sufficient analysis available for this current report to suggest applying these factors to asbestos measurement data for the WTC data.)

On this basis, the following summaries are excerpted from the profile (specific references supplied in ATSDR, 1999). It should be noted that these "background" data are derived from settings where no identified asbestos materials are present, as well as other settings, such as buildings containing asbestos materials where there may have been some local releases.

- Data from several studies indicate that in urban areas, most ambient air concentrations range from $3*10^{-6}$ to $3*10^{-4}$ PCM f/cc, but they may range up to $3*10^{-3}$ PCM f/cc as a result of local sources. In another investigation, the median concentration in U.S. cities has been estimated to be $7*10^{-5}$ PCM f/cc.

- A recent analysis of monitoring data for asbestos in ambient air worldwide estimated rural and urban levels at about $1*10^{-5}$ TEM f/cc ($2*10^{-7}$ PCM f/cc) and $1*10^{-4}$ TEM f/cc ($2*10^{-6}$

PCM f/cc), respectively.

- In a review of indoor air monitoring data from a variety of locations, arithmetic mean concentrations ranged from $3*10^{-5}$ to $7*10^{-3}$ PCM f/cc. Levels of asbestos in 94 public buildings that contained asbestos ranged from ND to 0.2 TEM f/cc (ND to 3*10-3 PCM f/cc), with an arithmetic mean concentration of 0.006 TEM f/cc (10-4 PCM f/cc). Analysis of data based on air samples from 198 buildings with asbestos-containing materials (ACM) indicated mean asbestos levels ranging from $4*10^{-5}$ to $2.43*10^{-3}$ TEM f/cc ($7*10^{-7}$ to $4*10^{-5}$ PCM f/cc).

- Asbestos concentrations in 41 schools that contained asbestos ranged from ND to 0.1 TEM f/cc (ND to $2*10^{-3}$ PCM f/cc), with an arithmetic mean of 0.03 TEM f/cc ($5*10^{-4}$ PCM f/cc). Another study reported average concentrations of airborne asbestos fibers > 5 μm in length of $8*10^{-5}$ TEM f/cc and $2.2*10^{-4}$ TEM f/cc in 43 non-school buildings and 73 school buildings, respectively (the 60:1 conversion factors would not apply to these data, since the TEM readings were already on fibers >5 μm in width, so they are likely to be more directly comparable to PCM results). In another study in 71 U.S. schools, the mean, the 95 percentile, and the maximum asbestos levels were $1.7*10^{-4}$, $1.4*10^{-3}$, and $2.3*10^{-3}$ PCM f/cc, respectively.

- A study of 49 buildings in the United States reported mean asbestos fiber levels of $9.9*10^{-4}$ PCM f/cc in buildings with no ACM, $5.9*10^{-4}$ PCM f/cc in buildings with ACM in good condition, and $7.3*10^{-4}$ PCM f/cc in buildings with damaged ACM.

In general, concentrations of asbestos in both indoor and outdoor settings and in both rural and urban settings appears to be less than, and by some studies, sometimes substantially less than, $3*10^{-3}$ f/cc on a PCM volumetric basis.

IV.e.4. Asbestos Air Monitoring Data at the WTC

Three sources of information were used to evaluate the asbestos air monitoring. One was the EPA WTC database itself. Downloads of this database occurred in May of 2002, and the data evaluated are current as of about mid-April, 2002. The WTC database includes measurements by several federal, state, and local agencies. The second source of data was the Trends Report dated May 16, 2002 (EPA, 2002a). There have been three Trend Reports. Generally, these reports obtain all their data from the EPA WTC database and provide summaries and interpretative analyses. The third source of data is a study commissioned by a "Ground Zero Elected Officials Task Force" to principally sample two apartments on September 18, 2001 (Chatfield and Kominsky, 2001). While the focus of that study was on the indoor environment (it is reviewed in more detail in Section V), two outdoor air samples were also taken.

The May Trends Report contains a summary of the PCM and TEM data collected between September 12, 2001 (the date of the first reported sample), and April 13, 2002, in the lower Manhattan area in the vicinity of Ground Zero. Additional TEM data from the Staten Island Landfill were obtained directly from the Region 2 WTC database. Figures 23 and 24 show the locations of fixed monitors at the Lower Manhattan and Staten Island Landfill areas,

respectively. A few more stations were set up in public schools (Manhattan - PS143, Queens - PS199, Brooklyn - PS274, Bronx - PS154, and Staten Island - PS44), and New Jersey (4 locations). There were over 600 samples taken in these public schools. Nearly all the samples were non-detected, with only one high reading of 93.3 S/mm^2 in PS199 in Queens on October 12, 2001, and 2 other low readings (< 20 S/mm^2). Over 100 samples were reported for the New Jersey locations through early December of 2001. Nearly all readings were non-detect with a few low measurements (< 20 S/mm^2).

On the basis of these findings, there does not appear to be any significant concern for a health impact at these Brooklyn, upper Manhattan, and New Jersey locations, and they are not discussed further.

The latest trends report (EPA, 2002a) summarizes the results of 8,870 samples taken from lower Manhattan and measured for TEM (locations in Figure 23). Samples taken during the time period between September 14 (the date of the first asbestos sample taken) and September 30 showed generally the highest concentrations. Table 6 lists the TEM measurements above 70 S/mm^2, and, as shown, more readings above this level were found for September (11 readings) than for any other month: October (2), November (1), December (1), January (1), February (2), March (3), and April (1).

The Trends Report also presents a directional analysis that supports this general observation in most cases. For this directional analysis, a subset of the sites was selected to represent the north, south, east, west, northeast, northwest, southeast, and southwest quadrants. Two-week maximums were then identified for each of these sites. These two maximums were plotted on 3-d graphs for N-S, E-W, NE-SW, and NW-SE. These graphs are duplicated in Figures 25 - 28 for TEM. The N-S graph in Figure 25, for example, shows that most of the samplers had their highest 2-week maximums during the first 2-week period identified, September 16 to September 30. Some samplers did have additional elevations later in time, such as Albany and Greenwich, which had a high reading of 204 S/mm^2 in December (from Figure 25 and also listed in Table 6).

The same general observation that early readings were the highest is seen in the NE-SW graph of Figure 28. These two graphs also do not exhibit a predominant wind direction: high measurements of the same magnitude were found on both the N and S sides (Figure 25) and the NE and SW sides (Figure 28). Figures 26 and 27, on W-E and NW-SE, do not show the same predominant elevations in September; concentrations are mostly level throughout time, with occasional elevated readings, such as a reading of 213 S/mm^3 in February, 2002, at Church & Dey (from Figure 26 and Table 6). It does appear that during 2002, most readings were at what appears to be background for the area, at nondetect or reported at less than 20 S/mm^2.

A number of samples at the Staten Islands Landfill recorded higher levels than the AHERA standard. This presumably results from WTC debris being unloaded at this location, which causes the asbestos structures to become airborne. The WTC database listed 5207 measurements in numerous Staten Islands Landfill sites (see Figure 24), and 50 samples were identified as above 70 S/mm^2. These are listed in Table 6. Unlike the air monitors near Ground Zero, which showed the most elevations in September, the most elevations in the landfills occurred fairly

uniformly in October and November. This was perhaps a time period of most rigorous unloading. Of the 50 readings above 70 S/mm^2, 36 occurred during these two months. The highest level of 275.56 S/mm^2 was observed on November 5, 2001.

The Trends Report (EPA, 2002a) summarizes the results of 12,674 ambient samples measured for PCM, of which 8870 were also measured for TEM. Figures 29 - 32 show the directional analysis results for PCM. It is noted that all samples were less than 0.1 f/cc. The trend observed above for TEM, that most high readings were found in the early readings in September, holds as well for PCM. The range of these higher measurements is about 0.04 to 0.08 f/cc, and only 7 measurements in this range are seen in Figures 29 - 32. As noted above, PCM analyses identify the presence of fibers, including fibers of materials other than asbestos. By December, the maximum 2-week readings were all at apparent background for the area. With a few isolated exceptions, levels ranging from non detect to about 0.003 f/cc had been observed from lower Manhattan sampling sites since February, 2002 (EPA, 2002a). This background is consistent with the background measurements in other locations summarized above.

Chatfield and Kominsky (2001) describe the sampling of two apartments one week after September 11, on September 18. In addition to sampling of indoor air and dust (described in Section V), and some outdoor dust, two samples of outdoor air were also sampled. One was at a residential dwelling characterized as "high", so named due to the expectation that higher concentrations would be measured within it. It was in an apartment building located on 250 South End Avenue, close to and southwest of Ground Zero. Apartment 10D, on the east side of this building and which had sustained window damage, was selected for sampling. Heavy dust deposits were in the apartment. One air sample at this site was taken by positioning the sampler outside a sliding window. The concentration of chrysotile asbestos (S > 0.5 μm) was 548 S/mm^2, which is the highest outdoor air measurement found. However, it is likely this high reading was influenced by the air quality on the inside of the apartment, which showed exceedingly high asbestos concentrations (>10,000 S/mm^3; see the discussion on this study in Section VI. Data on Occupational and Indoor Exposures), and was likely not representative of outdoor concentrations. The "low" location was located four blocks north on 45 Warren Street. The apartment building did not appear to sustain any external damage. Apartments on the second and fifth floors were sampled. A sample taken on the roof above the fifth floor apartment showed a reading of 6.5 S/mm^2 chrysotile asbestos.

IV.e.5. Human Health Evaluation of Asbestos Air Measurements

Only 22 of 8870 TEM measurements in lower Manhattan from EPA's WTC data base exceeded the AHERA standard of 70 S/mm^2, and one additional sample (of two taken) from an independent study exceeded the standard. The 12 exceedences, which occurred in September, were all at sites bordering Ground Zero: 250 South End Ave., Barclay & West Broadway, Albany & Greenwich, Liberty & South End, Vesey & West, and Albany & West. These sites were still in the restricted zone during September. The same general trend can be seen with the PCM data. Measurements near to or greater than 0.04 f/cc occurred mostly in September (6 of 7 samples during September, with 1 high sample during the first two weeks in October) and at sites bordering Ground Zero: Broadway & Liberty, Rector & South End, Albany & West, West Broadway & Barclay, Wall & Broadway, Albany & Greenwich, and Liberty & South End. It is

reasonable to conclude that general population exposures to ambient levels of asbestos were minimal and potential short- and long-term health impacts were minimal during the early weeks when a small percent of elevated measurements of asbestos were reported.

The potential for exposure appeared to be somewhat greater at the Staten Island Landfill. A total of 50 samples exceeded the AHERA standard of 70 S/mm^2, with most exceedences occurring during October and November. The average of the 36 exceedences during October and November was 92.6 S/mm^2. Exceedences in February through April of 2002 were likely due to the continued unloading of WTC debris. Assuming the crude TEM to PCM conversion factor of 1/60 used by ATSDR and the TEM surface area to volume conversion factor of $3*10^{-4}$ [f/cc]/[S/mm^2], then this converts to a PCM-equivalent concentration of 0.0005 f/cc. This is significantly lower than the OSHA PEL of 0.1 f/cc. It is reasonable to conclude that the exposure of workers to asbestos at the Staten Island Landfill was minimal and potential short- and long-term health impacts were minimal during the unloading of debris at the site.

Table 6. Locations and concentrations of asbestos exceeding the AHERA level of 70 S/mm^2.

Location	Date	Concen-tration	Date	Conc
I. Landfill Locations				
Location 01 Landfill	Apr 27	125.98		
Location 02 Landfill	Mar 23	170.6		
Location 05 Landfill	Mar 14	78.74		
Location 08 Landfill	Nov 5	112		
Location 09-A Landfill	Oct. 8	71.11	Nov 5	71.11
	Oct 25	128	Nov 11	120.0
	Oct 25	128		
Location 09-B Landfill	Oct 18	96.24	Nov 5	71.11
Location 09-C Landfill	Oct 17	97.78		
Location 10-A Landfill	Nov 7	80		
Location 11 Landfill	Oct 18	96.24	Feb 6	110.24
	Nov 6	80	Feb 7	170.6
	Nov 7	88.89	Feb 15	78.74
	Nov 17	80	Feb 16	78.74
Location 12a Landfill	Oct 8	88	Nov 12	80
	Oct 16	124.44	Nov 13	72
	Oct 18	96.24	Nov 20	71.11
	Oct 20	80	Jan 11	166.23
	Oct 31	115.56	Mar 21	157.48
	Nov 5	275.56	Mar 23	125.98
	Nov 11	195.56	Apr 20	104.99
Location 12b Landfill	Oct 25	115.56	Nov 5	106.67
Location 13 Landfill	Oct 15	80	Nov 13	97.78
	Oct 25	88.89		
Location 14 Landfill	Oct 17	80	Dec 11	104.99
	Oct 26	88.89	Dec 11	104.99
	Nov 7	80	Apr 3	91.86
Location 15 Landfill (mess tent)	Nov 6	90	Nov 18	97.78
Location 16 Landfill (supply tent)	Oct 20	72	Nov 9	80
II. Lower Manhattan Locations				
250 South End Avenue[a]	Sep 18	548		
Location A - Barclay St & West Broadway	Sep 15	128	Sep 15	160
Location B - Church St & Dey St	Feb 11	213.33		
Location C - Liberty St & Trinity St	Feb 5	88		
Location D - Albany St & Greenwich St	Sep 27	97.78	Dec 27	204.44
	Sep 30	88.88		
Location E - Liberty St & South End Ave	Sep 16	90	Sep 30	80
Location F - Vesey St & West St	Sep 27	71.11		

Table 6 Locations and concentrations of asbestos exceeding the AHERA level of 70 S/mm² (cont'd).

Description	Date	Conc	Date	Conc
Location K - Albany & West St	Sep 22	80	Sep 27	177.78
	Sep 23	88.89	Sep 30	71.11
Location L - North Side of Stuyvesant High	Nov 28	124.44		
Location V - Pier 6 Bus Sign	Jan 14	72		
Wash Tent - West St. Between Murray & Vesey	Mar 9	144	Mar 30	96
	Mar 29	96	Apr 2	80
Site 2 - Chambers Street	Oct 9	104.99		
Public School 199 in Queens	Oct 12	93.33		

[a] This sample was reported on in Chatfield and Kominsky (2001); all other data was from the EPA WTC data base. See text for more detail.

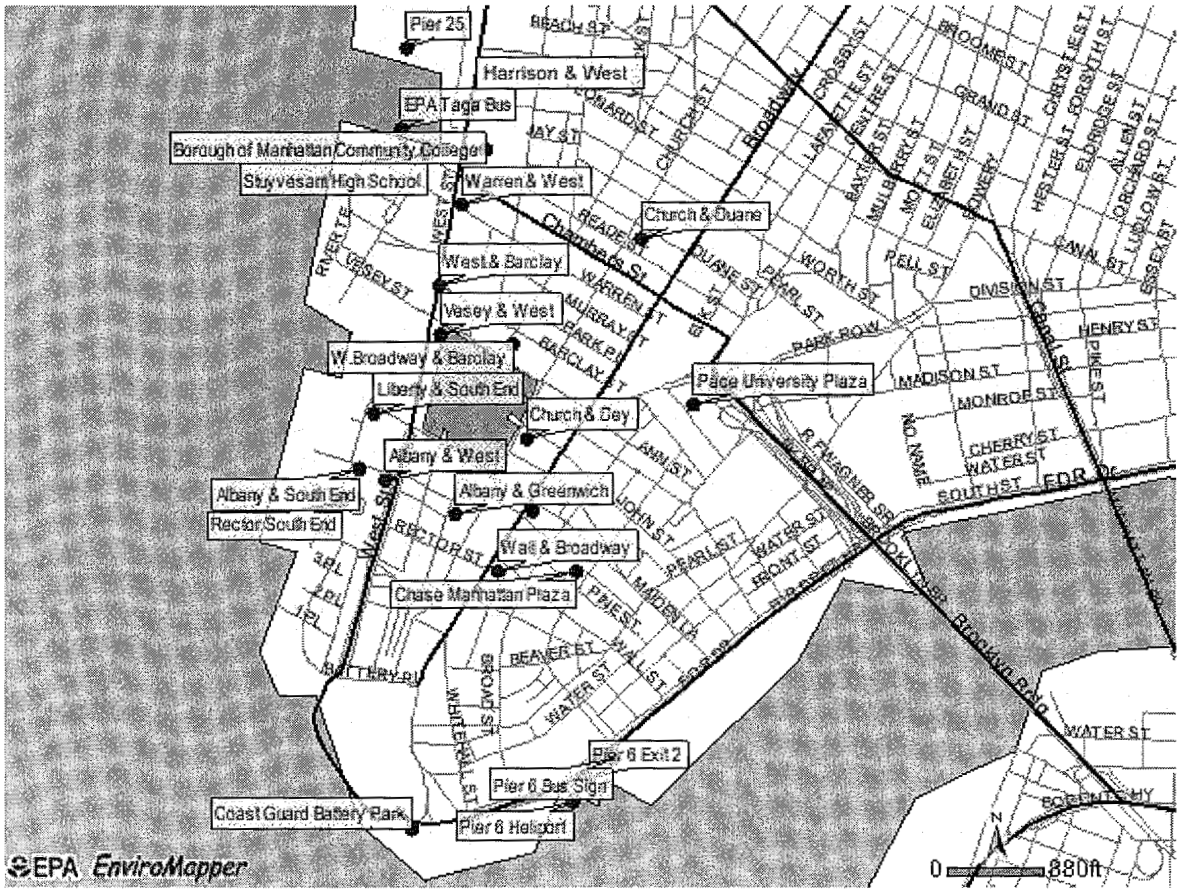


Figure 23. Location of asbestos monitoring stations in Lower Manhattan.

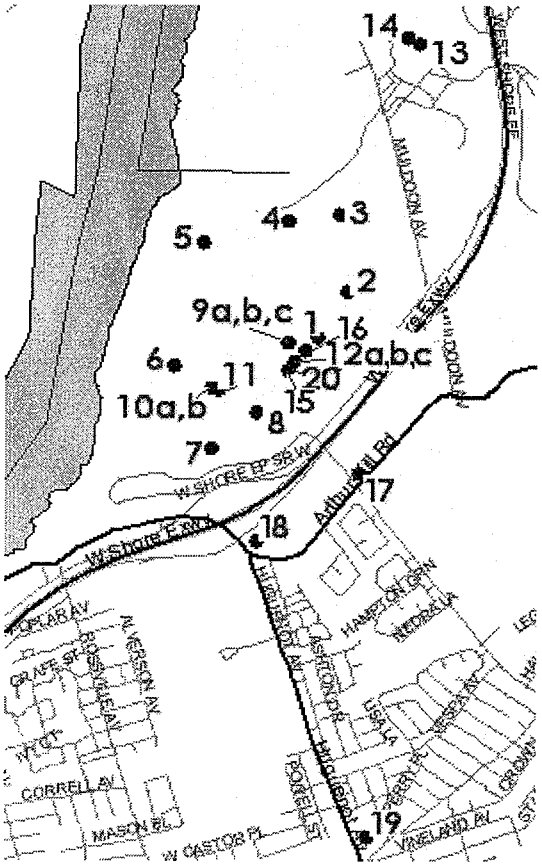


Figure 24. Location of Asbestos monitoring stations in Staten Island and nearby locations in New Jersey (note: sampling sites in the Staten Island Landfill identified only by number).

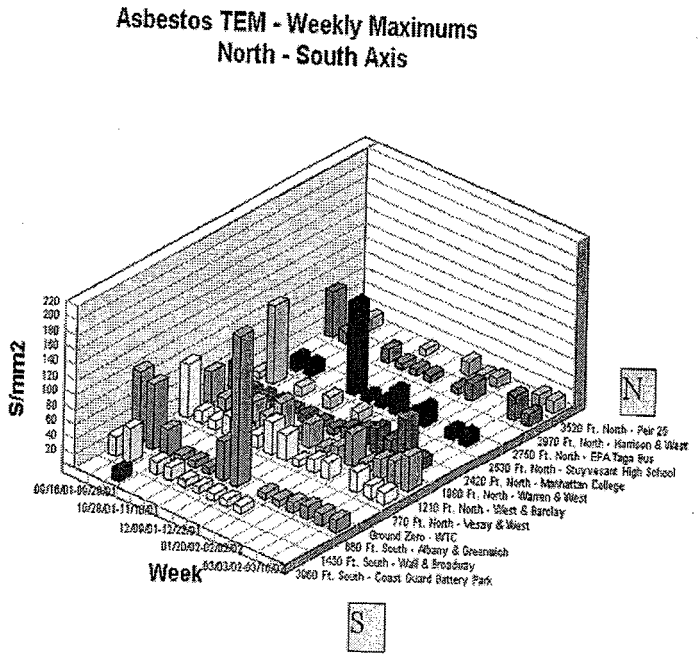


Figure 25. North-South directional analysis for asbestos TEM weekly maximums (taken from EPA, 2002a).

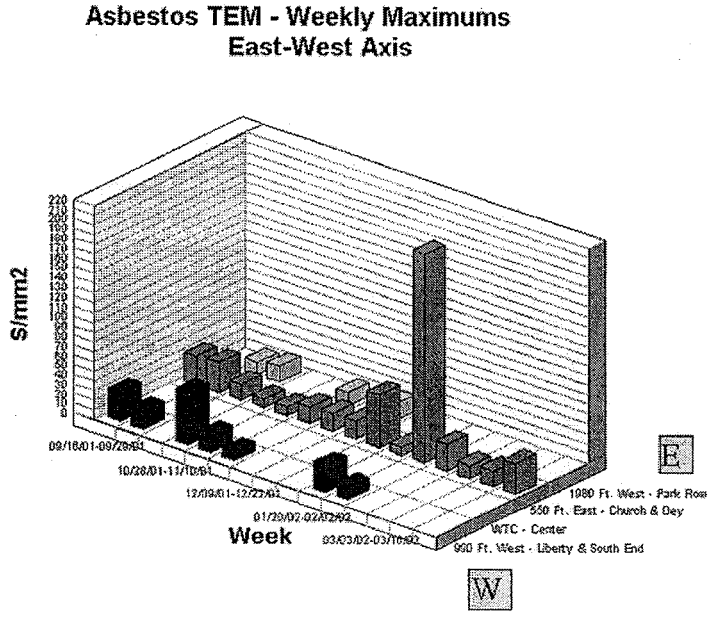


Figure 26. East-West directional analysis for asbestos TEM weekly maximums (taken from EPA, 2002a)

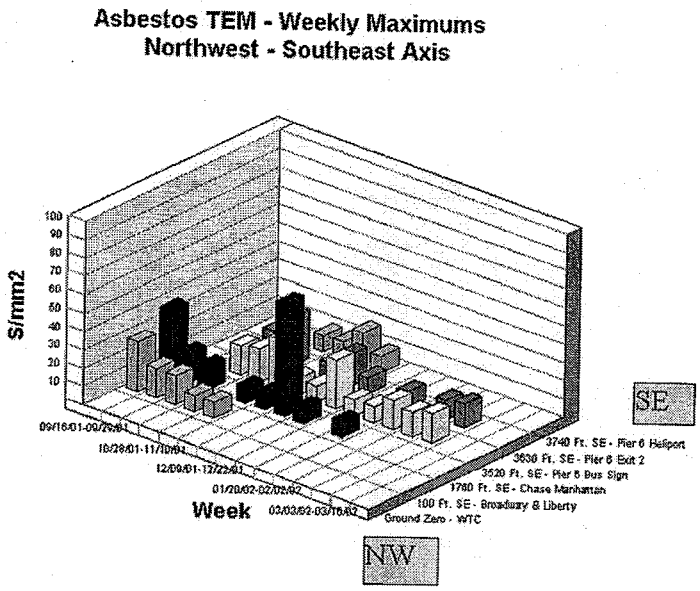


Figure 27. Northwest-Southeast directional analysis for asbestos TEM weekly maximums (taken from EPA, 2002a).

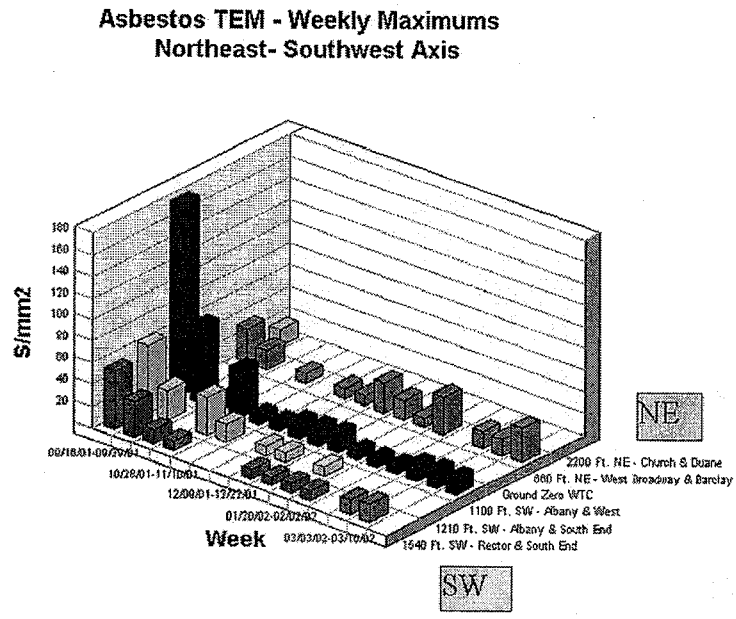


Figure 28. Northeast-Southwest directional analysis for asbestos TEM weekly maximums (taken from EPA, 2002a).

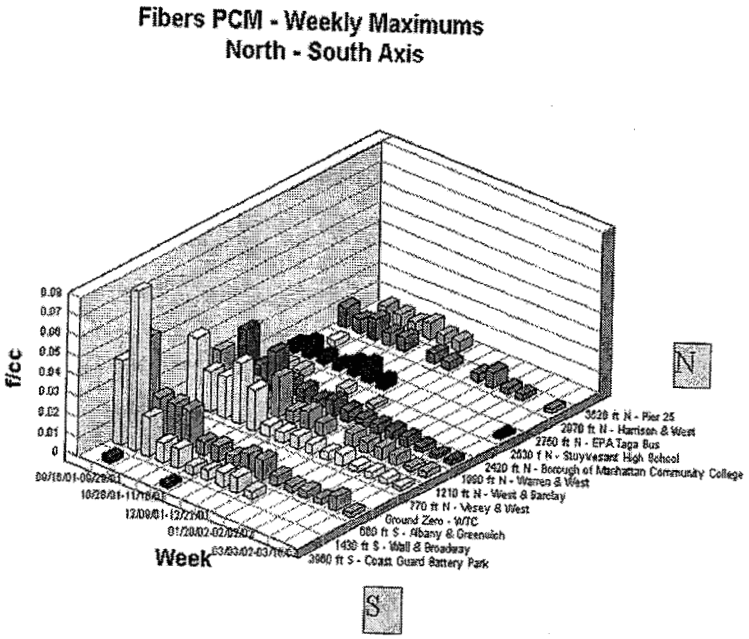


Figure 29. North-South directional analysis for asbestos TEM weekly maximums (taken from EPA, 2002a).

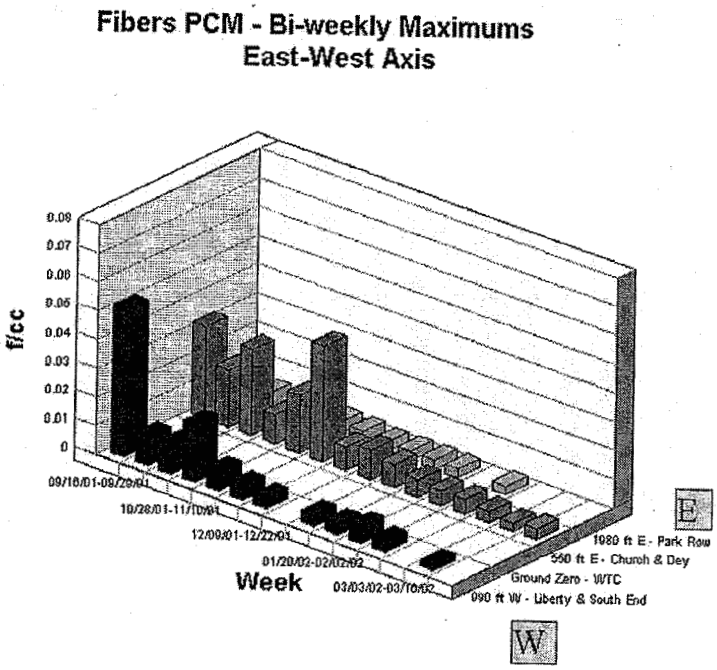


Figure 30. East-West directional analysis for asbestos TEM weekly maximums (taken from EPA, 2002a)

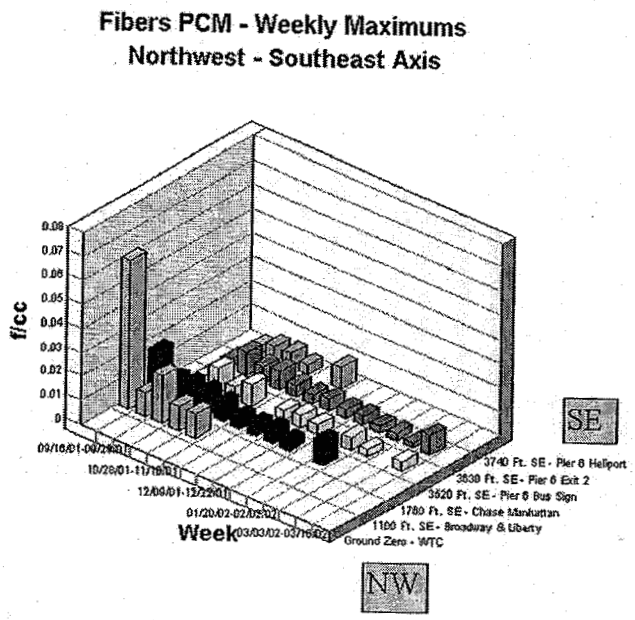


Figure 31. Northwest-Southeast directional analysis for asbestos TEM weekly maximums (taken from EPA, 2002a).

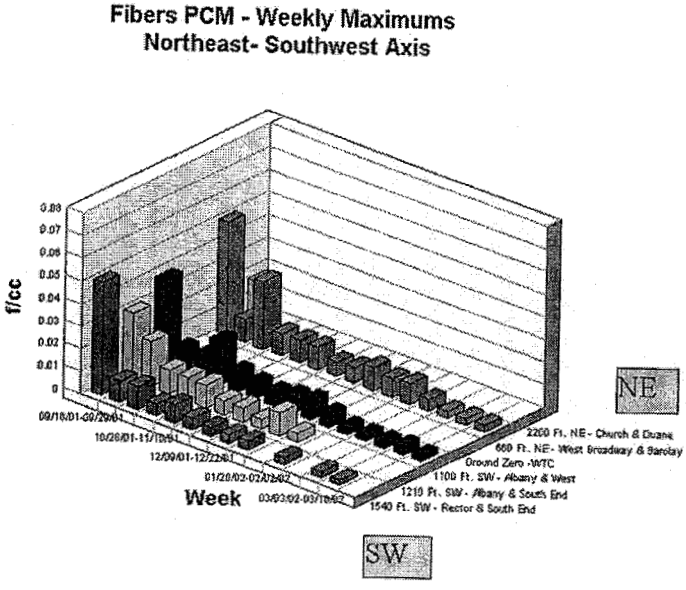


Figure 32. Northeast-Southwest directional analysis for asbestos TEM weekly maximums (taken from EPA, 2002a).

IV.f. Volatile Organic Compounds (VOCs)

VOCs are carbon compounds that exist exclusively in the gaseous phase in the ambient environment and include benzene, toluene, chloromethane, ethylbenzene, acetone, and styrene. VOCs have been associated with a variety of health effects, including immunologic, hematotoxic and neurologic effects; chromosomal damage; and cancer. VOCs are produced as a result of combustion of products containing carbon, such as plastics, wood, paper, carpeting, gasoline, and jet fuel. Thus, they would have been produced as a result of the WTC disaster.

Analysis of all VOCs released at the World Trade Center would require evaluating hundreds of different compounds. The list was narrowed down by emergency response personnel, representatives from EPA headquarters, EPA Region 2, NYSDEC, and NYSDOH. In this assessment, data for 14 VOCs were examined and screened, including acetone, benzene, 1,3 butadiene, chloromethane, 1,4 dioxane, ethanol, ethylbenzene, freon-22, methyl styrene, propylene, styrene, tetrahydrofuran, toluene, and xylenes. These VOCs were chosen on the basis of frequency of detection, concentration, toxicity, and carcinogenicity. Two of these 14 VOCs, freon-22 and methyl styrene, were not systematically measured outside of Ground Zero. Freon-22 was measured only at the WTC Chiller Plant and methyl styrene was only measured at Ground Zero. For this reason, freon-22 and methyl styrene are not evaluated in this report. Additionally, because no screening standards are available for propylene, a health assessment cannot be conducted for this chemical. Therefore, a total of eleven VOCs were evaluated for this report.

To evaluate the VOC exposures, a variety of screening benchmarks were used, including OSHA PELS and STELS, ATSDR acute and intermediate inhalation MRLs, and EPA Superfund Technical Support Center (STSC) provisional subchronic RfCs. If none of these benchmarks were available, the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) for an 8-hour exposure and the NIOSH RELS were used. The goal of this assessment was to evaluate effects due to short-term exposure, thus screening tools that are based upon lifetime exposures to a chemical (i.e. EPA RfC values or ATSDR chronic MRLs) were not used.

IV.f.1. Evaluation of VOCs at Ground Zero

The majority of the EPA data collected for VOCs were within Ground Zero (North Tower Center, South Tower Center, and Austin Tobin Plaza) and nearby locations. For example, for acetone, benzene, ethylbenzene, and 1,3 butadiene, more than 500 samples were taken in the restricted zone near and within Ground Zero, where authorized personnel were directed to wear respirators. The majority of the measurements taken were grab samples that were usually collected within a 4-minute period. Samples at North Tower Center and South Tower Center were taken in potential hot spot areas such as plumes, areas of fire and combustion, and steam releases. The efforts at these two locations were subjective and were intended to capture potential worst case emissions. Samples at Austin Tobin Plaza were taken at a breathing zone height, but were still grab samples and were not purposively where workers were currently working, but where they might work or where there was visible smoke to contend with. Thus, collected samples at the three sites cannot be considered representative of the general air quality to which workers were exposed. Rather, the principal purpose of the EPA sampling at Ground

Zero was to provide results within four hours to alert the Fire Department of New York (FDNY) and the contractors/union health/safety officers working at Ground Zero about conditions that posed immediate health concern to the workers. This sampling was specifically requested by the FDNY and was conducted on a daily basis until the removal activities were completed at Ground Zero (end of May 2002).

As would be expected given this intention, some of the results (including data for benzene, 1,3-butadiene, and styrene) did show exceedences of OSHA limits. A few samples clearly demonstrated exceptionally high measurements of VOCs produced as a result of the disaster. Some samples were collected on top of, and at times, inside the actual debris pile, clearly demonstrating subjective sample design. Because the VOC sampling at the site is not believed to be representative of actual exposures to personnel, it would not be appropriate, or valid, to use these VOC sampling data to analyze worker exposures.

OSHA collected approximately 700 samples for organic compounds, as described in Chapter VI. Most of these samples were taken using personal air monitors, and the samples were taken over longer periods (one to eight hours) and are representative of a worker's breathing zone exposure. As described in Chapter VI, the OSHA data did not show routine exceedences of screening values (the OSHA standards). For that reason, WTC worker exposures will not be evaluated further. Instead, sampling data that were collected at sites surrounding the WTC site were used to evaluate potential health risks to persons who live or work in surrounding areas.

IV.f.2. Evaluation of VOCs at Sites Surrounding Ground Zero

The EPA WTC monitoring database and data from EPA-ORD monitors were used to evaluate VOC exposures to persons who may live and work in areas surrounding the WTC site. Most of the data in the WTC monitoring database are from EPA sampling, but data from other groups (e.g., NYSDEC, OENHP) are also included. Data from the WTC monitoring database covered approximately 27 locations and the EPA-ORD monitors covered 5 locations.

A map of the VOC sampling locations outside of Ground Zero is shown in Figure 33. Table 7 lists the site name, street address, approximate dates of sampling and the approximate number of samples that were taken. Because the number and dates of sampling varied depending on the VOC, the sample dates and number of samples taken shown in the table are for benzene monitoring only. These numbers are, in general, representative of the dates and frequency of sampling of the other VOCs.

Exceedences of benchmark standards were seen for 6 of the 11 VOC compounds evaluated in this assessment, including acetone, benzene, 1,3-butadiene, chloromethane, ethylbenzene, and toluene. 1,4 Dioxane, ethanol, styrene, tetrahydrofuran, and xylenes showed no exceedences of screening benchmarks at any of the sampling sites and are therefore not considered to be contaminants of concern at sites surrounding Ground Zero. Table 8 lists the sites that showed exceedences of screening benchmarks, the dates of exceedence, and the location of the site in relation to the restricted zone. Tables 9-14 show the exceedences of these 6 VOC compounds.

For 5 of these 6 VOC compounds, data were also available for 24-hour samples taken by

EPA; 24-hour samples were not available for chloromethane. These 24-hour sample results are also provided in Tables 9, 10, 11, 13, and 14 to compare with the exceedences (Table 12 is chloromethane).

Chemical-by-chemical summaries of the 6 VOCs that exceeded benchmarks are presented below.

Acetone: Most people are exposed to acetone through consumer product use, including nail polish remover, particle board, and paint removers. Acetone exposure may also occur as a by-product of exposure to isopropyl alcohol. The typical level of acetone in the air in cities in the United States is about 0.007 ppm (ATSDR, 1994). Acute exposure to acetone at levels above 100 ppm may cause irritation to the nose, throat, lungs, and eyes (ATSDR, 1994).

A total of 264 acetone monitoring results were evaluated at sites surrounding Ground Zero. A summary of the screening benchmarks and exceedences is shown in Table 9. All three exceedences were seen at Greenwich and Liberty. Two of the exceedences were on September 28, where grab samples found concentrations of 29 ppm and 22 ppm. On October 1, a concentration of 20 ppm was detected. The other 12 samples taken at Greenwich and Liberty did not show concentrations above 13 ppm, including the samples taken on September 26 and September 27, as well as October 2, October 3, and February 23.

The monitoring data indicate that the acetone level was found to elevated above a typical background (0.007 ppm as noted above) in grab samples for 4 days only on the end of September and beginning of October just off the southern portion of Ground Zero. Because this would correspond to an acute exposure, the ATSDR acute MRL screening value of 26 ppm (ATSDR, 1994) is most appropriate. This value was only slightly exceeded in one sample on 1 day (29 ppm). The Greenwich and Liberty sampler location was in the restricted zone at the time of the exceedence and it was unlikely that residents would be present in that area.

Twenty-four hour samples were taken on September 27 and for three days in December. As seen in Table 9, these locations bordered Ground Zero and the day-long concentration was nearly 4 orders of magnitude (10,000 times) lower than the grab samples, and well within the range of the cited typical background of 0.007 ppm. This clearly demonstrates that sampling within a "hot spot" can result in very high concentrations that are representative of only the few minutes during which the grab sample is taken .

Benzene: Benzene is widely used in the production of other chemicals. It is also found in crude oil, gasoline, and cigarette smoke. Excluding occupational exposures, the major sources of benzene exposure are tobacco smoke, automobile service stations, automobile exhaust, and industrial emissions. Urban air concentrations of benzene can vary widely, depending on mobile source pollution. One large urban study (ATSDR, 1997a) detected a median benzene level of 0.013 ppm. Background concentrations reported by EPA Region 2 for benzene are 0.00051 ppm and 0.00053 ppm (annual averages of Brooklyn and Staten Island locations, respectively, over the period 1994 - 98; EPA, 2002b).

Breathing levels of benzene above 100 ppm can cause drowsiness, dizziness, and

unconsciousness. Long-term continued exposures to benzene will depress and may cause damage to the blood-forming system, as seen by a decrease in red and white blood cells, lymphocytes, platelets, and other blood constituents. However, after exposure has ended, red blood cell levels may return to normal. Benzene can also harm the immune system and increase the chances of infection and cancer. Benzene is a known human carcinogen, causing leukemia. Most of what is known about the acute and chronic effects of benzene comes from animal and human studies where decreases in bone marrow function have been measured. The intermediate MRL, 0.004 ppm, was derived from a study in mice, where changes in locomotor activity were seen after exposure to 0.78 ppm benzene for 2 hours a day for 30 days. A 100-fold uncertainty factor was used to derive the intermediate MRL (ATSDR, 1997a).

A total of 332 benzene monitoring results were evaluated at sites surrounding Ground Zero. A summary of the screening benchmarks and exceedences is shown in Table 10. According to sampling notes for other VOCs with the same sample number, all these samples were taken at ground level, and the October 1 measurement was taken at ground level in a plume. Nine measurements taken at Greenwich and Liberty between September 16 and September 26, and on October 2 and October 3, were at levels below 0.02 ppm. From these data, it appears that exceedences did not last more than 5 days. Furthermore, these exceedences all occurred within the restricted zone. At Liberty and Trinity, the exceedence detected was 11 ppm on September 26. According to sampling notes for other VOCs with the same sample number, this measurement was taken at ground level in a plume. Measurements taken on September 16, September 22, September 23, and on October 26 did not show exceedences.

From these data, it appears that the exceedence did not last longer than 32 days and throughout this period was in a restricted zone. Because previous sampling did not show exceedences, it is likely that the measurement was taken deliberately in a plume to represent a worst-case transient exposure.

For the 262 samples recorded in the WTC EPA database for sites surrounding Ground Zero, the minimal detection limit was 0.02 ppm, as compared to the ATSDR intermediate MRL of 0.004 ppm (ATSDR, 1997a). This means that the analytical method could not detect benzene contamination levels below 0.02 ppm. Therefore, one cannot evaluate whether or not the ATSDR intermediate MRL was exceeded because the detection level for the samples was higher than the intermediate MRL. Five samples exceeded the ATSDR acute MRL of 0.05 ppm (ATSDR, 1997a), and these are shown in Table 10. Four samples had values above 0.02 ppm but below the 0.05 ppm level. The rest of the samples in the EPA WTC database were reported to be 0.02 ppm. These values are not reported above. Sample results reported to be below 0.05 ppm (257 sampling results) were not screened against the intermediate MRL.

Results from the 70 EPA-ORD samples show that the OSHA PEL and STEL values for benzene were never exceeded. Since these EPA-ORD samples did have a lower detection than the samples reported on in the WTC EPA database, they could be compared against the ATSDR intermediate MRL of 0.004 ppm. It was found that the ATSDR acute and intermediate MRL values were exceeded a total of 17 times at 4 different sampling sites. At West Broadway and Park Place, 10 samples were taken between November 9, 2001, and January 3, 2002. They showed benzene levels to be below the intermediate MRL. Additionally, exceedences at West

Broadway and Park Place were not found on October 15, October 16, October 17, and October 22 (the highest value was only 0.002 ppm). The range of sampling results (0.002 to 0.026 ppm) shows the temporal variability in the benzene levels. At 290 Broadway from November 26 through January 3, 10 samples were taken. They showed benzene levels to be below the intermediate MRL. At Broadway and Liberty, the sample taken on October 17, the only sample taken after the exceedence on October 8, was below the intermediate MRL at 0.0009 ppm. At Albany and West, 16 samples were taken between October 22 and January 3. They showed the benzene levels to be below the intermediate MRL.

Monitoring results from the EPA-ORD sampling suggest that benzene never exceeded screening benchmarks for more than 45 days. At all the sites there was great temporal variability in the samples. The largest gap between an exceedence of the intermediate MRL and a value below the MRL was only 11 days at West Broadway and Park Place. For 290 Broadway, Broadway and Liberty, and Albany and West, the first samples below screening benchmarks were taken November 26, September 22, and September 23, respectively. If one assumes that exposures began September 11, the worst case exceedences of the intermediate MRL could not have lasted longer than 45, 8, and 18 days, respectively, at 290 Broadway, Broadway and Liberty, and Albany and West. Thus the worst-case, longest possible exposure, would have been 45 days at 290 Broadway.

On the basis of data summarized above, it is concluded that the exceedences measured at Liberty and Trinity, Greenwich and Liberty, W. Broadway and Park Place, Broadway and Liberty and Albany and West were not a public health risk to residents. These sites were in the restricted zone or on the border of the zone, and it is unlikely that residential exposures occurred for extended periods. The samples taken were grab samples (taken within a 4 minute period) and are not representative of the average exposures. Samples taken at Liberty and Trinity and Greenwich and Liberty were purposefully taken at ground level and/or in a plume and are not representative of average breathing zone exposures. The temporal variability of the other samples, as shown by exceedences intermixed between days that were below screening benchmarks, also leads to the conclusion that exceedences of the Intermediate MRL were not sustained for extended periods of time. For exposures lasting less than 14 days, the acute MRL is a more appropriate health screening benchmark, and this value was not exceeded at these sites.

At 290 Broadway, elevated measurements were found as late as October 11 (see Table 10) and exposures could have occurred, as the measurement was taken in a non-restricted zone. In a worst-case scenario, the longest possible exposure would have been 45 days at this site. At this site, measurements were taken on a 16th floor balcony. Whether or not the VOC samples collected at this site are representative of the breathing zone exposures will depend on the meteorology and air mixing at the site. The highest benzene value measured at this site was 0.007 ppm and the intermediate MRL is 0.004 ppm (ATSDR, 1997a). Adverse effects would not be expected at 0.004 ppm, and it is unlikely that adverse effects would occur at 0.007 ppm.

The 24-hour samples are mostly lower than all the grab sample exceedences; only the finding of 0.005 ppm at Church and Dey on September 28 approached the grab samples listed as exceeding the ATSDR Intermediate MRL of 0.004 ppm. This Church and Dey location is on the edge of Ground Zero which was also restricted on September 28. In the northwest direction on

September 28, at the Vesey and West and the EPA Taga Bus locations showed a very low 24-hour concentration, 0.00081 at Vesey and West and ND at EPA Taga Bus. This demonstrates that concentrations were likely higher in the general direction of plume movement, which on September 28 was likely in the east direction.

Of all the VOC data, the benzene data does suggest that sustained concentrations above the typical New York City background could have occurred for about a month after September 11 outside of Ground Zero. As noted above, the background concentration reported by EPA Region 2 for benzene is about 0.0005 ppm. Four of the nine 24-hour measurements taken on September 28 exceeded this background. The grab sample exceedences were substantially higher than this background, and there were several exceedences above the ATSDR Intermediate MRL of 0.004 ppm. Whether or not specific health effects occurred due to exposure to benzene is unknown, but given that the exceedences and elevations above typical background were near Ground Zero and mostly within restricted zones, the data suggests that exposures to the general population were of minimal concern.

1,3-Butadiene: 1,3-Butadiene is found in automobile exhaust, wood smoke, and cigarette smoke, and in the breakdown of other materials. 1,3-Butadiene is almost always found at low levels in urban air samples, but it breaks down very quickly. In sunny weather, the half-life of 1,3-butadiene is only 2 hours. The median concentration of 1,3-butadiene in urban air has been estimated at approximately 0.0003 ppm (ATSDR, 1993).

A total of 304 1,3-butadiene monitoring results were evaluated at sites surrounding Ground Zero. A summary of the available screening benchmarks and exceedences is shown in Table 11. One exceedence of the 1.0 ppm PEL was detected in a ground-level plume on October 1, at 1.5 ppm. On days preceding and following October 1 the levels of 1,3-butadiene measured at this location were below the screening benchmark; in fact, 10 of the 12 samples taken at this location were at 0.002 ppm.

All 24-hour samples were non-detects for 1,3-butadiene.

Chloromethane: Chloromethane is always present in the air at very low levels. Most of the naturally occurring chloromethane comes from chemical reactions that occur in the oceans or that occur when materials such as grass, wood, charcoal, and coal are burned. Reported urban levels of chloromethane have been between 0.00066 and 0.00096 ppm (ATSDR, 1998). The background concentration reported by EPA Region 2 for chloromethane is approximately 0.00029 ppm (the annual average for a Staten Island location for the period 1995-1999; EPA, 2002b).

High-level exposures - above 100 ppm - to chloromethane can cause nervous system damage and adversely affect the liver, kidney, and heart. Lower-level exposures - above 50 ppm - have been shown to cause delayed growth, liver changes, and neurological effects in animals. Data do not exist to determine health effects that would be seen with short-term, very low-level exposures. The EPA-STSC provisional subchronic RfC, the screening benchmark with the lowest acceptable exposure limit, is based on a 2-year animal study that showed neurological effects and liver and kidney damage at 1000 ppm but not at 225 ppm (EPA, 1998).

A total of 257 chloromethane monitoring results were evaluated at sites surrounding Ground Zero. A summary of the available screening benchmarks and exceedences is shown in Table 12. As with all VOCs, all grab sample exceedences were taken in a restricted zone, and in the time frame from late September to early October. It is noted that all of the samples that showed exceedences at Greenwich and Liberty were taken at ground level and that the October 1 measurement was taken at ground level in a plume. Measurements taken at this site September 24 - 27 and on October 2 and 3 were all at levels below 0.02 ppm. From these data, it appears that exceedences did not last more than 4 days. At Liberty and Trinity, the exceedence detected was 0.82 ppm on September 26, and it was noted that this measurement was taken at ground level in a plume. Measurements taken on September 22, September 23, and on October 26 did not show exceedences.

Ethylbenzene: Ethylbenzene occurs naturally in petroleum and coal tar and can be released into the air from burning oil, gas, and coal The median level of ethylbenzene in city and suburban air is about 0.00062 ppm (ATSDR, 1999).

Breathing high levels of ethylbenzene (above 100 ppm) can cause dizziness, tightness in the chest, and eye and throat irritation. Short-term exposure of laboratory animals to high concentrations of ethylbenzene in air may cause liver and kidney damage, nervous system changes, and blood changes. No data exist to evaluate the short-term effects of low levels of ethylbenzene exposure in humans or animals. The EPA-STSC provisional subchronic RfC for ethylbenzene is adopted directly from the EPA RfC for a lifetime exposure. The EPA-STSC confidence level in this derivation is low. The EPA RfC is based on developmental effects seen in female rats that were exposed to ethylbenzene throughout their pregnancy. Adverse effects in this study were not seen at levels below 100 ppm (EPA, 1999a).

A total of 338 ethylbenzene monitoring results were evaluated at sites surrounding Ground Zero. A summary of the available screening benchmarks and exceedences is shown in Table 13. As with the other VOCs, exceedences occurred in the restricted zone in the latter part of September and early October. A value of 0.4 ppm ethylbenzene was detected at Liberty and Trinity and it was noted that this sample was taken in a ground-level plume. Three samples obtained between September 16 and September 23 and a breathing zone sample taken on October 26 were all below 0.05 ppm.

The 24-hour ethylbenzene samples that were detected were three orders of magnitude (1000 times) lower than these grab sample exceedences; 10 out of 13 samples were non-detected. This demonstrates again the difference between grab samples taken within a plume and the 24-hour average concentration of the VOC.

Toluene: Toluene occurs naturally in crude oil and is added to gasoline. Toluene is also used in making paints, paint thinners, fingernail polish, lacquers, and adhesives. It can also be detected in cigarette smoke. Urban concentrations of toluene have been estimated to be around 0.003 ppm (ATSDR, 2000b). The background concentration reported by EPA Region 2 for toluene is approximately 0.002 ppm (annual average for a Brooklyn location over the period 1994 - 1998).

High-level exposures to toluene (above 100 ppm) may affect the nervous system and kidneys. Headaches, confusion, and sleepiness are also seen after high-level exposures. A short-term exposure study (4 days) in human subjects showed eye and nose irritation and neurological effects at 100 ppm; these effects were not seen at 40 ppm. The EPA-STSC provisional subchronic RfC for toluene is adopted directly from the EPA RfC for a lifetime exposure. The EPA-STSC confidence in this value is medium. This value is derived from a study where workers were exposed to 88 ppm of toluene for 6 years. In this study, adverse neurological effects were seen in the workers (EPA, 1999b).

A total of 335 toluene monitoring results were evaluated at sites surrounding Ground Zero. A summary of the available screening benchmarks and exceedences is shown in Table 14. The available benchmarks that were exceeded were the ATSDR acute MRL of 1 ppm and the EPA-STSC provisional subchronic RfC of 0.25 ppm. At Greenwich and Liberty, measurements taken on September 28 were collected in ground-level grab samples; on October 1, the sample was taken in a ground-level plume. Measurements taken at this site on September 16 through September 27 and on Oct 2 and 3 were all at levels below 0.02 ppm. From these data, it appears that exceedences did not last more than 4 days. At Liberty and Trinity, the September 26 sample was collected in a ground level plume. Four samples obtained between September 16 and September 23 and a breathing zone sample taken October 26 were all below 0.05 ppm.

The 24-hour toluene samples were three orders of magnitude (1000 times) lower than these grab sample exceedences. Similar to ethylbenzene, 1,3-butadiene, and acetone, this difference in toluene concentrations between the grab sample exceedences and the 24-hour samples demonstrates the difference between grab samples taken within a plume and the long-term average concentration of the VOC.

Findings from VOC monitoring: As discussed above, most of the samples that showed exceedences were short duration grab samples that were taken in a plume or at ground level, not in the breathing zone. In fact, the exceedences for benzene, ethylbenzene, chloromethane and toluene measured at Liberty and Trinity on September 26, all came from the same collected grab sample which was taken in a plume. Similarly, all the exceedences measured at Greenwich and Liberty for acetone, 1,3-butadiene, benzene, chloromethane and toluene, came from the same 3 collected grab samples. Because these are 4-minute grab samples, it is not known how long the plume lasted - from minutes to hours to days. These exceedences all occurred in late September and early October; available grab sample data before and after these exceedences are all lower in value. In addition to being grab samples, all exceedences occurred within restricted zones or just on the border of the restricted zones. Finally, all 24-hour samples of four of the VOCs - ethylbenzene, 1,3-butadiene, acetone, and toluene - were lower than the grab samples, by about a factor of 1000. On the basis of the available monitoring data, it is concluded that the exceedences of the screening benchmarks in the restricted zone did not represent a public health risk to persons living or working at sites surrounding Ground Zero for at least these four VOCs.

The data for benzene was not as definitive. When compared with the other VOCs, the 24-hour benzene samples were measured at levels that were closer in magnitude to the grab sample exceedences, within a factor of 10. This would suggest that the grab sample concentrations were

closer to sustained concentrations rather than short-term plume concentrations only. Also, these 24-hour concentrations were near the ATSDR Intermediate MRL of 0.004 ppm and higher than the historical average for New York City of about 0.0005 ppm. The data suggests that the exposures to benzene at levels that approach the MRL were no longer than 45 days. Whether or not specific health effects occurred due to exposure to benzene is unknown, but given that the exceedences and elevations above typical background were near Ground Zero and mostly within restricted zones, the data suggests that exposures to the general population were of minimal concern.

Table 7. VOC sampling locations outside of Ground Zero.

Site Name	Street Location	Sampling Dates for Benzene	Number of Samples Taken
ORD Site A	W. Broadway & Park Place	Sept 22- Jan 3	22
ORD Site B	290 Broadway	Sept 25-Jan 3	14
ORD Site C	Broadway & Liberty	Sept 23-Oct 17	6
ORD Site C′	Cedar & Trinity	Nov 7-Nov 12	4
ORD Site K	Albany & West	Sept 23-Jan 3	24
	140 Broadway	Sept 28	6
	75 Park Place & Greenwich	Sept 28	8
	Albany & Washington	Sept 16	2
	Church & Vessey	Feb 13	2
	Greenwich & Liberty	Sept 16-Feb 23	15
	Liberty & Trinity	Sept 12-Sept 26	6
	Liberty & West	Sept 16-Oct 5	10
Loc A	Barclay & W Broadway	Sept 22-Sept 27	3
Loc B	Church & Dey	Sept 16-Oct 10	3
Loc C	Broadway & Liberty	Sept 27	1
Loc D	Albany & Greenwich	Sept 27	1
Loc E	Liberty & South End	Sept 27	1
Loc F	Vessey & West	Sept 16-Sept 27	2
Loc K	Albany & West	Sept 23-Sept 25	2
Loc N	Pier 25 (southside)	Oct 13	1
Loc P	Albany & South End	Sept 27	1

Table 7. VOC Sampling Locations Outside of Ground Zero (cont'd).

Site Name	Street Location	Sampling Dates for Benzene	Number of Samples Taken
Loc R	EPA TAGA Bus	Sept 23-Jan 1	11
Loc S	Rector Pl & South End	Sept 27	1
	Murray St & W Broadway	Oct 12-Oct 14	3
	Murray St betw West & N End	Nov 5-Mar 31	134
	Rockefeller Park	Sept 18-Nov 7	37
	Park Pl (225 Rector)	Sept 28	6
	Park Row & Spruce	Oct 14	1
Site 1 (NYSDEC)	Park Row	Oct 12-Oct 13	2
Site 16	290 Broadway	Sept 25	1
	130 West (Verizon Building)	Sept 29	1
	South of Building 4	Sept 25	1

Table 8. Locations that showed exceedences of screening benchmarks for VOCs and restrictions to access.

Location	Dates of Exceedence	Restrictions to Access
West Broadway and Park Place	Sept 22, Sept 25, Oct 3, Oct 9, Oct 19, Oct 20, Oct 21, Oct 24	in the restricted zone until Sept 27, was a border of the restricted zone until Oct 24
290 Broadway	Sept 25, Sept 26, Sept 27, Oct 11	in the restricted zone until Sept 19
Broadway and Liberty	Sept 23, Oct 8	in the restricted zone until Jan 28
Albany and West	Oct 1, Oct 20	was in the restricted zone until Oct 24, and became, and still is, a border of the restricted zone as of May 8
Liberty and Trinity	Sept 26	was in the restricted zone until Feb 12, and became, and still is, a border of the restricted zone as of May 8
Greenwich and Liberty	Sept 27, Sept 28, Oct 1	still in the restricted zone as of May 8

Table 9. Acetone grab sample exceedences and 24-hour sample monitoring summary.

I. Grab Samples			
Acetone Screening Benchmarks	**Exceedence concentration**	**Exceedence Location and Date**	**Restricted Zone**
OSHA PEL 1000 ppm[1]		None	
ATSDR Acute MRL 26 ppm[2]	29 ppm	Greenwich and Liberty Sept 28	Yes
ATSDR Intermediate MRL 13 ppm[2]	22 ppm 20 ppm	Greenwich and Liberty Sept 28 Greenwich and Liberty Oct 1	Yes Yes
II. 24-Hour Samples			
Location		**Concentration (ppm)**	**Date**
Albany and Greenwich		0.0064	Sep 27
Albany and South End		0.0066	Sep 27
Barclay and West Broadway		0.0071	Sep 27
Church & Dey		0.0078	Sep 27
EPA Taga Bus		0.012 0.0056 0.0040 0.0044 0.0048	Sep 27 Sep 27 Dec 3 Dec 10 Dec 17
Liberty and Broadway		0.0053	Sep 27
Liberty and South End		0.010	Sep 27
Rector and South End		0.0069	Sep 27
Vesey and West		0.0045	Sep 27

[1]NIOSH (2002)
[2]ATSDR (1994)

Table 10. Benzene grab sample exceedences and 24-hour sample monitoring summary.

I. Grab Samples			
Benzene Screening Benchmarks	**Exceedence Concentration**	**Exceedence Location and Date**	**Restricted Zone**
OSHA PEL 1 ppm[1] OSHA STEL 5 ppm[1]	11 ppm 19 ppm 49 ppm 1.3 ppm	Liberty and Trinity Sept 26- Greenwich and Liberty Sept 28 Greenwich and Liberty Sept 28 Greenwich and Liberty Oct 1	Yes Yes Yes Yes
ATSDR Acute MRL 0.05 ppm[2]	0.1 ppm	Greenwich and Liberty Sept 27 samples noted above also exceed the ATSDR acute MRL	Yes
ATSDR Intermediate MRL 0.004 ppm[2]	0.011 ppm 0.024 ppm 0.026 ppm 0.007 ppm 0.012 ppm 0.008 ppm 0.016 ppm 0.008 ppm 0.005 ppm 0.007 ppm 0.0043 ppm 0.005 ppm 0.021 ppm 0.007 ppm 0.024 ppm 0.008 ppm 0.008 ppm	W. Broadway and Park Pl. Sept 22 W. Broadway and Park Pl. Sept 25 W. Broadway and Park Pl. Oct 3 W. Broadway and Park Pl. Oct 9 W. Broadway and Park Pl. Oct 19 W. Broadway and Park Pl. Oct 20 W. Broadway and Park Pl. Oct 21 W. Broadway and Park Pl. Oct 24 290 Broadway Sept 25 290 Broadway, Sept 26 290 Broadway, Sept 27 290 Broadway Oct 11 Broadway and Liberty Sept 23 Broadway and Liberty Oct 8 Albany and West Sept 30 Albany and West Oct 1 Albany and West Oct 20	Yes Yes Border Border Border Border Border Border No No No No Yes Yes Yes Yes Yes

II. 24-Hour Samples		
Location	**Concentration (ppm)**	**Date**
Barclay and West Broadway	0.0025	Sep 27
Vesey and West	0.00081	Sep 27
Liberty and South End	<0.0007	Sep 27
Albany and South End	<0.0007	Sep 27
Rector and South End	<0.0007	Sep 27

Table 10. Benzene grab sample exceedences and 24-hour sample monitoring summary (cont'd).

II. 24-Hour Samples		
Location	**Concentration (ppm)**	**Date**
Church and Dey	0.005	Sep 27
Liberty and Broadway	0.002	Sep 27
Albany and Greenwich	<0.0007	Sep 27
EPA Taga Lab	<0.0007 <0.0007 <0.0007 0.0007 0.0007	Sep 27 Sep 27 Dec 3 Dec 10 Dec 17

[1]NIOSH (2002)
[2]ATSDR (1997)

Table 11. 1,3-Butadiene grab sample exceedences and 24-hour sample monitoring summary.

I. Grab Samples			
1,3-Butadiene Screening Benchmarks	**Exceedence Concentration**	**Exceedence Location and Date**	**Restricted Zone**
OSHA PEL 1 ppm[1] OSHA STEL 5 ppm[1]	1.5 ppm	Greenwich and Liberty Oct 1	Yes
II. 24-Hour Samples			
Location		**Concentration (ppm)**	**Date**
Albany and Greenwich		<0.0028	Sep 27
Albany and South End		<0.0027	Sep 27
Barclay and West Broadway		<0.0027	Sep 27
Church & Dey		<0.0026	Sep 27
EPA Taga Bus		<0.0027 <0.0026 <0.0034 <0.0027 <0.0026	Sep 27 Sep 27 Dec 3 Dec 10 Dec 17
Liberty and Broadway		<0.0027	Sep 27
Liberty and South End		<0.0027	Sep 27
Rector and South End		<0.0027	Sep 27
Vesey and West		<0.0027	Sep 27

[1]NIOSH (2002)

Table 12. Chloromethane grab sample exceedences monitoring summary.

Chloromethane Screening Benchmarks	Exceedence Concentration	Exceedence Location and Date	Restricted Zone
OSHA PEL 100 ppm[1]		None	
ATSDR Acute MRL 0.5 ppm[2]	8.3 ppm 11 ppm 17 ppm 0.82 ppm	Greenwich and Liberty Sept 28 Greenwich and Liberty Sept 28 Greenwich and Liberty Oct 1 Liberty and Trinity, Sept 26	Yes Yes Yes Yes
ATSDR Intermediate MRL 0.2 ppm[2]		same as above	
EPA-STSC Provisional Subchronic RfC 0.14 ppm[3]		same as above	

[1]NIOSH (2002)
[2]ATSDR (1998)
[3]EPA (1998)

Table 13. Ethylbenzene grab sample exceedences and 24-hour sample monitoring summary.

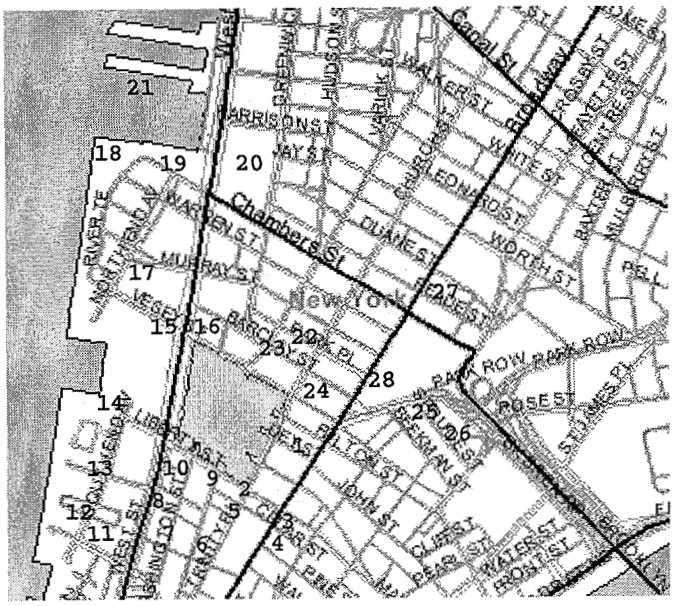
I. Grab Samples			
Ethylbenzene Screening Benchmarks	**Exceedence Concentration**	**Exceedence Location and Date**	**Restricted Zone**
OSHA PEL 100 ppm[1]		None	
ATSDR Intermediate MRL 1 ppm[2]	4.0 ppm 4.7 ppm 1.7 ppm	Liberty and Greenwich Sep 28 Liberty and Greenwich Sep 28 Liberty and Greenwich Oct 1	Yes
EPA-STSC Provisional Subchronic RfC 0.23 ppm[3]	0.4 ppm	same as above Liberty and Trinity Sept 26	Yes
II. 24-Hour Samples			
Location		**Concentration (ppm)**	**Date**
Albany and Greenwich		<0.0007	Sep 27
Albany and South End		<0.0007	Sep 27
Barclay and West Broadway		0.0011	Sep 27
Church & Dey		0.0022	Sep 27
EPA Taga Bus		<0.0007 <0.0007 <0.0009 <0.0007 <0.0007	Sep 27 Sep 27 Dec 3 Dec 10 Dec 17
Liberty and Broadway		0.001	Sep 27
Liberty and South End		<0.0007	Sep 27
Rector and South End		<0.0007	Sep 27
Vesey and West		<0.0007	Sep 27

[1]NIOSH (2002)
[2]ATSDR (1999)
[3]EPA (1999a)

Table 14. Toluene grab sample exceedences and 24-hour sample monitoring summary.

I. Grab Samples			
Toluene Screening Benchmarks	**Exceedence Concentration**	**Exceedence Location and Date**	**Restricted Zone**
OSHA PEL 200 ppm[1]		None	
ATSDR Acute MRL 1 ppm[2]	7.5 ppm 9.0 ppm 3.7 ppm 1.8 ppm	Greenwich and Liberty Sept 28 Greenwich and Liberty Sept 28 Greenwich and Liberty Oct 1 Liberty and Trinity Sept 26	Yes Yes Yes Yes
EPA-STSC Provisional Subchronic RfC 0.25 ppm[3]		same as above	
II. 24-Hour Samples			
Location		**Concentration (ppm)**	**Date**
Albany and Greenwich		0.0014	Sep 27
Albany and South End		0.0019	Sep 27
Barclay and West Broadway		0.0020	Sep 27
Church & Dey		0.0033	Sep 27
EPA Taga Bus		0.0009 0.0007 0.0018 0.0017 0.0015	Sep 27 Sep 27 Dec 3 Dec 10 Dec 17
Liberty and Broadway		0.0019	Sep 27
Liberty and South End		0.0014	Sep 27
Rector and South End		0.001	Sep 27
Vesey and West		0.0015	Sep 27

[1]NIOSH (2002)
[2]ATSDR (2002b)
[3]EPA (1999b)



Key

1 = Church & Dey
2 = Liberty & Trinity
3 = Broadway & Liberty
4 = 140 Broadway
5 = Cedar & Trinity
6 = Albany & Greenwich
7 = Albany & Washington
8 = Albany & West
9 = Greenwich & Liberty
10 = Liberty & West
11 = 225 Rector Place
12 = Rector & South End
13 = Albany & South End
14 = Liberty & South End
15 = Vessey & West
16 = 130 West (Verizon bldg)
17 = Murray St (between West & North End)
18 = Rockefeller Park
19 = EPA Taga Bus
20 = Barclay & West Broadway
21 = Pier 25
22 = Murray & West Broadway
23 = 75 Park Place & Greenwich
24 = Church & Vessey
25 = Park Row & Spruce
26 = Park Row
27 = 290 Broadway
28 = West Broadway and Park Place

Figure 33. Location of VOC monitoring stations outside Ground Zero.

Section V. Comment on the First Several Days After September 11

An event such as September 11 demonstrates that the greatest environmental impacts occur in the first 24 to 48 hours and in areas close to the site. Difficulties associated with site access and security, power supply sources, equipment availability and analytical capacity hindered efforts by EPA and the New York State Department of Environmental Conservation (NYSDEC) to put air monitors in place immediately after the attack. Region 2 collected numerous samples of dust on September 11 and the next few days, and analyzed them for asbestos and lead. However, the first air samples of some of the critical contaminants from Ground Zero and nearby were not taken until September 14, such as asbestos, while other contaminants were not sampled until September 23, such as dioxin. Rapid initiation of monitoring will allow the measurement of air concentrations that can be very important for evaluation of inhalation exposures and potential short and long-term human health impacts.

Therefore, very little data are available to quantify exposures which could have occurred in the hours and days following the collapse of the WTC towers on September 11. As discussed in all of the individual contaminant sections, the general trend was that air concentrations were elevated in the earliest samples, and that concentrations appeared to return to background within weeks to a few months. The section on particulate matter (PM) went further by speculating on what the air concentrations of PM might have been in the initial plume cloud that occurred on September 11, based on an empirical relationship between visibility and PM concentration. The PM section also included discussions on the findings published by Lioy et al. (2002), who sampled dust which had settled onto cars and other surfaces, and had been undisturbed when their sampling occurred a few days after September 11. The USGS has similarly sampled and reported on measurements of contaminants in dust and debris (http://speclab.cr.usgs.gov/wtc/). Modeling studies within EPA to evaluate the movement of plumes in the few days after September 11 are ongoing (preliminary results are presented in the PM section), and these may shed light on exposures which could have occurred during these few critical days. Epidemiological studies may also elucidate information on exposures during the first few days after September 11.

It seems apparent that higher concentrations would have been found in the time frame of about September 11 to September 18 compared to the concentrations that were found when monitors did get in place. The earliest ambient monitoring data within Ground Zero and in the closest monitors are the asbestos sampling results which were measured first on September 14. Benzene and PCB measurements were reported for September 16. Lead was reported starting on September 18, and $PM_{2.5}$ was reported first on September 21. The first measurements for dioxin-like compounds were not available until September 23.

Table 15 lists the first measurements on dioxin, asbestos, and lead in samplers within Ground Zero (the "WTC" sampler) and at locations bordering Ground Zero (e.g., Church & Dey). The data on that table supports the hypothesis that higher concentrations were likely to have been present within the first few days after September 11 as compared to when monitoring did begin. As seen, generally the highest concentrations were the very first ones available or within the first week or two of sampling. It is also noted that for dioxin and lead, the monitoring stations on South End Avenue (Liberty & South End, Albany & South End, and Rector & South

End) were showing very low background measurements on these first days of sampling at the same time the samplers within the plume - the WTC sampler and the Church & Dey sampler - were showing very high concentrations.

These data and similar data for other contaminants underscore the importance of being able to monitor very early after such an event. It is also recognized that a major uncertainty for the evaluations presented in this report is the lack of information on exposures which could have occurred within that first critical week after September 11.

Table 14. Summary of the first measurements of dioxin TEQs, asbestos, and lead at locations within or very near Ground Zero.

Contaminant	Concentration; Location; Sampling Date	Later Measurements and Other Comments
Dioxin TEQ, pg/m^3	160 WTC 9/23 170 WTC 10/2 170 WTC 10/4	All subsequent measurements were less than 100 pg TEQ/m^3 through 5/28/02. Note: Upwind monitors on South End (Liberty, Albany and Rector) all showed NDs on 9/23, indicating that elevations were tied to plume.
	130 Church/Dey 9/23	No further samples > 10 pg/m^3; samples through 5/17/02
	100 Liberty/Broadway 9/23	No further samples > 10 pg/m^3; samples through 10/26/01
Asbestos, S/mm^2	160 Barclay/W Broadway 9/14 ND Barclay/W Broadway 9/15 128 Barclay/W Broadway 9/15	All subsequent Barclay/W Broadway lower than 100 S/mm^2.
	80 Albany/West 9/22 89 Albany/West 9/23 178 Albany/West 9/27 71 Albany/West 9/30	Concentrations were less than 70 S/mm^2 on Sep. 17, 18, 20, and 21, but no measurements above 70 after 9/30.
	48 Liberty/S. End 9/14 90 Liberty/S. End 9/15 (dup) 53 Liberty/S. End 9/15 80 Liberty/S. End 9/30	There were measurements between 9/15 and 9/30 that were less than 50 S/mm^2, but no measurements after 9/30 above 50 S/mm^2
Asbestos[a], f/cc	0.1 Fulton/Church 9/13 0.078 Fulton/Church 9/26 0.059 Fulton/Church 9/28	All subsequent measurements after 9/28 were under 0. 04 f/cc (through 8/03/02), but 6 samples between 9/15 and 9/19 were between 0.020 and 0.034, and samples on 10/1 and 10/3 were at 0.035 and 0.023, respectively.
	0.035 Vesey[b] 9/16 0.024 Vesey[b] 9/17	Next samples on 10/6-10/9 were between 0.008 and 0.023; no samples taken after 10/9.
	0.035 Fulton[c] 9/15 0.030 Fulton[c] 9/16	One sample on 9/14 was below LOQ; no samples taken after 9/16.
	0.020 Liberty/Church 9/14 0.021 Liberty/Church 9/18	One sample on 9/14 was below LOQ; no samples taken after 9/18.
Lead, μg/m^3	4.3 Barclay/W. Broadway 9/23 2.8 Barclay/W. Broadway 9/27	One sample > 1.0 μg/m^3 on 10/4, otherwise, all samples < 0.6 μg/m^3; samples through 2/5/02
	1.9 Church/Dey 9/18 1.7 Church/Dey 9/23	all other < 0.7 μg/m^3; samples through 2/5/02.
	5.4 WTC 9/23	next sample at WTC on 10/2 was 1.1, and one other 1.1 on 10/15, but otherwise all samples < 0.8 through 2/5/02. Similar to dioxin, all South End sampling locations had very low findings in initial 9/23 samples.

[a] All of these samples taken by and reported by the NYCDEP.
[b] Actual location was described as, Vesey between Church and Broadway.
[c] Actual location was described as, Fulton between Church and Broadway.

Section VI. Data on Indoor and Occupational Exposures

This section provides a summary of data that are available, or that are being generated, from Ground Zero sites where rescue, clean-up and other workers may have been present, and on the indoor air environment. The occupational exposure data are related directly only to the workers on Ground Zero who were potentially exposed to contaminants generated during the course of their work . The indoor exposure data relate to residents in buildings off of Ground Zero whose exposure is from contaminated air that may have infiltrated their living or working spaces during or at some point after the disaster. It is emphasized that this section does not provide any human health risk evaluations in the way that ambient air data were evaluated in Section IV, except when summarizing conclusions of the original authors of the data.

VI.a. Data From Ground Zero Relating to Occupational Exposures

The Occupational Safety and Health Agency (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have generated data sets on air quality at Ground Zero. These data sets are summarized below. Further information on the data and the evaluation of these data can be obtained through the web sites that are identified below.

As part of the evaluations contained in this report, exposures to PCBs and dioxin toxic equivalent (TEQ) concentrations that were measured at Ground Zero were evaluated for on-site workers, which could include workers involved in rescue and clean-up operations. That evaluation is summarized here, with reference to the more detailed evaluations in Sections IV.

VI.a.1. OSHA Data

The OSHA data are posted on their Ground Zero monitoring web-site, at http://www.osha.gov/nyc-disaster/summary.html. Further information on these data can be obtained from OSHA, with contacts provided at, http://www.osha.gov. No interpretative analysis of the OSHA data, other than an identification of exceedences of benchmarks, is provided on the web site or from other available sources.

A total of 1434 asbestos samples (excluding bulk and blank samples) were taken. From September 19-21, 177 samples were taken in the financial district. Since September 21, sampling focused on the WTC site and those workers working in or immediately next to it. A total of 179 of the samples analyzed exceeded OSHA's PEL of 0.1 f/cc. However, upon further analysis using discriminating counting methods and/or TEM analysis, the number of asbestos fibers found dropped dramatically to below detectable levels or well below 0.1 f/cc.

The web site also summarizes data taken on CO, total dust, respirable silica, several organic compounds including PCBs, PAHs, dioxins, VOCs, and others, freon-22, hydrogen fluoride, phosgene, inorganic acids, oxides of nitrogen/sulfur, metals including lead, mercury, arsenic, and others, ionizing radiation, and noise. The web site indicates very few exceedences of OSHA PELs or other relevant benchmarks.

The results for respirable silica suggested some exposure. Of 1353 silica samples, 94 exceeded the PEL. The highest sample result was approximately twenty-one times the OSHA limit (jack hammering concrete 16 feet below grade). The other elevated exposures were

approximately one to fourteen times the OSHA limit. These exposures occurred during: 1) pre-drilling /slurry wall 2) jack hammering, 3) rubble removal and loading operations near the Winter Garden; 4) during the breaking up of concrete in the pit; 5) while drilling the concrete slurry wall, 6) flagging operations in pit, and 7) while chipping concrete with power tools during demolition activities at 7 WTC's parking garage. Most of the work areas where apparent overexposures to silica occurred were in the rubble pile/pit.

Similar to other results, very few exceedences of organic compounds were identified, including one exceedence for the benzene OSHA Allowable Limit of 1 ppm, and 8 PAH exceedences of OSHA's coal tar pitch volatile PEL of 0.2 mg/m^3 .

For metals, OSHA took a total of 1331 samples (excluding bulk and blank samples) to monitor worker exposures to dusts, fumes, oxides, and other compounds of metals such as antimony, beryllium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, vanadium, zinc, cadmium, magnesium, and arsenic. Results from these samples were generally well below the applicable OSHA limits. However, torch cutting and burning structural steel at the rubble pile resulted in instances of overexposures as follows: copper (17); iron oxide (28); lead (19); zinc oxide (1), antimony (1); and cadmium (3).

There were 236 samples collected for employee noise, and 20 samples exceeded the OSHA PEL of 90 dBA.

VI.a.2. NIOSH Data

The NIOSH sampling occurred between September 18 and October 14, 2001. The focus was on search-and-rescue personnel, heavy equipment operators, and workers cutting metal beams, but other occupations were also sampled. A total of 1174 air samples were taken, including 804 for asbestos. The New York City Department of Health and Mental Hygiene (NCDOHMH) collected most of the asbestos samples, while NIOSH personnel collected all other samples. In addition to air samples, 33 samples of dust, debris, and other materials were taken. NIOSH has reported on results for asbestos, metals, respirable particulate, CO, hydrogen sulfide, inorganic acids, VOCs, elemental carbon, Freon™-22, and PAH (CDC, 2002).

The bulk samples mostly showed asbestos concentrations at <1% (by mass); 3 of 29 samples had mass concentrations ranging from 1-3%. Analysis of air samples for asbestos by PCM revealed fibers in 358 of 804 samples (45%). Of 25 samples measured by PCM which exceeded the 0.1 f/cc REL, 18 were measured then by TEM, and all had asbestos concentrations less than 0.1 f/cc. Differential analysis by polarized light microscopy of these 25 air samples revealed that most nonasbestos fibers were fibrous glass, gypsum, and cellulose.

Air concentrations of total (36 samples) and respirable (18 samples) particles showed maximum concentrations of 2.3 and 0.3 mg/m^3, respectively, which are below the corresponding RELs of 10 and 5 mg/m^3 for Portland cement. Respirable crystalline silica was not detected in any of the 18 samples measured for it.

Two instantaneous peak CO measurements exceeded the 1,200 ppm level (at 1239 and 1369 ppm), the level NIOSH considers an immediate danger to life and health. One was from a

torch cutter and the other from a gasoline-powered saw operator. In 99 other samples, concentrations of CO ranged from 0.2 to 242.0 ppm. This high value was from a 32 minute sample, and it exceeded the NIOSH limit of 200 ppm and would have exceeded the PEL of 50 ppm had it been sustained for 2 hours.

CDC (2002) contains descriptions of all other contaminants measured. In general, nearly all samples were below relevant limits. An "Editorial note" at the end of the article (CDC, 2002, p. 455) concludes that, "At the time of the NIOSH sampling, the ambient air did not appear to be contaminated with toxic substances from the building or their contents or with combustion products to an extent that posed an occupational health hazard."

V1.a.3. Occupational Exposure to PCBs and Dioxins

These two classes of compounds were measured at Ground Zero (WTC Building 5 monitor) and for several locations just off-site. It was judged that EPA's 8-hour continuous air monitoring data on these two classes of compounds was adequate to be evaluating worker exposures in Section IV. These evaluations are contained in Sections IV.c (PCBs) and IV.d (dioxins), and are summarized here.

For PCBs, the highest concentration measured was 153 ng/m^3, which was measured at Ground Zero. All other measurements were less than 100 ng/m^3, with most at ND or within a typical urban range of 1-8 ng/m^3. These are much lower than the NIOSH REL at 1000 ng PCB/m^3 as an 8-hr time weighted average air concentration (NIOSH, 2002) and the OSHA PEL at 500,000 ng PCB/m^3 as an 8-hr time weighted average air concentration (NIOSH, 2002). Using EPA procedures for estimating 95% upper bound cancer risk, an individual exposed to the highest concentration found at 153 ng PCB/m^3 for a period of one month is estimated to have an excess lifetime cancer risk of about $2*10^{-8}$. EPA regulatory programs, such as the Superfund Program, typically consider individual incremental cancer risk estimates made in this manner (i.e., in the context of a scenario-based risk assessment) in the range of 10^{-4} to 10^{-6} to be of potential significance, depending on the circumstances. On this basis, an incremental cancer risk estimate in the range of 10^{-8} is judged to be insignificant.

For dioxins, potential cancer and non-cancer risk were assessed using methods that are detailed in EPA's Draft Dioxin Reassessment (EPA, 2000). First, a "scenario" is defined, which describes the pathways of exposures, contact rates with dioxin within these pathways, and the concentrations of dioxin in the exposure media. The scenario for the Ground Zero worker was as follows: this individual is exposed 10 hours per day, 5 days per week, in the time period between September 12 until November 30, 2001. The pathway of exposure is via inhalation, and the rate of inhalation for a WTC worker is 1.3 m^3/hr. Using data from the Ground Zero monitor, the average concentration during this time was calculated as 60.7 pg TEQ/m^3. Exposure during that time, expressed in terms of mass inhaled divided by body weight and time (pg TEQ/kg-day) is converted to a lifetime dose, and when combined with the appropriate dioxin cancer slope, a 95% upper bound estimate of cancer risk was estimated as $3*10^{-6}$, which is about 2 orders of magnitude lower (100 times lower) than current US background cancer risk to dioxin-like compounds. This background risk is primarily due to ingestion of foods of animal origin. For non-cancer risk, a newer approach based on calculation of an incremental increase to background body burden was employed. The dose over the three month exposure period was used in a

simple model to predict body burden increase, and it was found that the exposure of the WTC workers suggests that their body burden could rise up to 10% above current average background. These cancer and non-cancer results resulting from dioxin exposure were evaluated as not significant risks over average background risks for this class of compounds.

VI.b. Data on Indoor Environments

EPA Region 2 is currently conducting extensive monitoring and clean-ups of indoor residences. Much of the information on this effort can be seen on the following website:www.epa.gov/wtc. Part of their effort is to also evaluate background conditions, so that measurements can be compared to this background. It is expected that this effort will provide data from which EPA can conduct further health risk assessments. Also, EPA's Region 2 has been collecting data from various public and private monitoring efforts, and have provided a tabular summary of their preliminary compilation for use in this report (table provided by M. Maddaloni, Region 2, to M. Lorber, EPA Washington, August 18, 2002). The Agency for Toxic Substances and Disease Control (ATSDR) has conducted the only systematic study of the residential environment to date, and the results of their efforts are summarized below. Other summaries are provided below only for the systematic efforts that have been conducted or are underway.

VI.b.1. ATSDR Study on Apartments in Lower Manhattan

The New York City Department of Health and Mental Hygiene (NYCDOHMH) and ATSDR have released the Final Report of the Public Health Investigation to Assess Potential Exposures to Airborne and Settled Surface Dust in Residential Ares of Lower Manhattan (NYCDOHMH/ATSDR, 2002). From November 4 through December 11, 2001, environmental samples were collected in and around 30 residential buildings in lower Manhattan. In addition, four buildings above 59th Street were sampled and used as a comparison area for this investigation.

Bulk dust samples were collected both indoors and on outdoor surfaces and analyzed for the presence of asbestos by both the PLM (polarized light microscopy) and TEM methods. PLM can distinguish between fiber types in a bulk sample by their unique appearance and color when viewed under different wavelengths of light. Asbestos was detected in settled indoor dust in 10 out of 57 (18%) residential units sampled, with the positive samples showing a maximum of 1.5% asbestos in dust. By comparison no asbestos was detectable in dust samples collected in the 5 comparison residences. In outdoor dust collected at Lower Manhattan properties, asbestos was detected in 6 of 14 (43%) samples, with a maximum asbestos concentration in dust of 3.4%.

Importantly, airborne fibers were not detected above background levels (stated as 0.003 f/cc -- fibers meeting criteria for optical visibility) in any of the indoor air samples collected at the 57 residences in Lower Manhattan. Some understanding of the protocol design is needed to interpret the air sampling data. All air filter samples were analyzed first using PCM to determine if fibrous materials were present. If the PCM count (which does not distinguish fiber type) exceeded a 0.003 f/cc level identified as background (using the upper Manhattan measurements), then a TEM analysis for asbestos fibers was performed. Airborne asbestos fibers (meeting equivalent criteria for optical visibility) were not detectable in any TEM analyses (generally <

.001 f/cc).

However, since only a minority of the sampling locations (6) had PCM counts above background, and hence were analyzed by TEM; results are not conclusive regarding the potential for low levels of airborne asbestos (i. e., at levels < 0.003 f/cc -- fibers meeting criteria for optical visibility). In this regard it should be noted that the specific residences that had detectable asbestos in indoor dust did not have elevated airborne PCM levels and TEM data were not collected for these residences. Note that when conditions allowed the residential sampling utilized an "aggressive" methodology involving the operation of the vacuum exhaust, used for settled dust sample collection, to stir the air. Additionally, evidence of elevated asbestos levels was not found in air samples collected in common areas of the apartment buildings or in adjoining outdoor areas.

The NYCDOHMH/ATSDR Final report also included data on synthetic vitreous fibers (SVF or fibrous glass) concentrations in indoor and outdoor dust samples at the same residential locations. SVF (PLM analysis) was detected in a larger number of indoor dust samples (26 of 57 or 46%) and at higher concentrations (range 2-35%) than asbestos. In outdoor dust at these properties, SVF was detected in 11 of 14 (79%) of samples (concentration range 15 - 72%). As with asbestos, the study did not provide evidence of airborne SVF above background levels in indoor air samples collected at the residences in lower Manhattan. PCM measurements will detect SVF, and in those locations where air samples had total PCM fibers exceeding background, Scanning Electron Microscopy (SEM) also reexamined filters for SVF. While such fibers were detectable in two samples, all samples were below 0.001 f/cc.

Air and settled surface dust samples were also analyzed for mineral components of concrete (quartz, calcite, and portlandite) and mineral component of building wallboard (gypsum, mica, and halite). The X-ray diffraction analysis (XRD) analysis for crystalline minerals in air and settled surface dust is reported by NYCDOHMH/ATSDR as semiquantitative (labeled with a "J"). Air sampling for minerals detected quartz and other building-related materials in lower Manhattan. The other forms of crystalline silica were not detected in any air samples except for a one-time detection of cristobalite. The estimated concentrations of these minerals in air were low. In some locations, mineral components of concrete (quartz [3-19 $\mu g/m^3J$], calcite [ND-14 $\mu g/m^3J$], and portlandite [ND-95 $\mu g/m^3J$]) and mineral components of building wallboard (gypsum [4-15 $\mu g/m^3J$] and mica [ND-43 $\mu g/m^3J$]) were detected in air samples at higher estimated levels in lower Manhattan residential areas than in samples taken at comparison residential areas above 59th Street (quartz up to 6 $\mu g/m^3J$, calcite up to 6 $\mu g/m^3J$, portlandite up to 30 $\mu g/m^3J$, gypsum up to 6 $\mu g/m^3J$, and mica up to 17 $\mu g/m^3J$). Quartz, calcite, portlandite and gypsum appear to make up a higher percentage of dust in some buildings in lower Manhattan when compared to settled surface dust samples from buildings above 59th Street. Quartz was detected up to an estimated 31%J versus up to 2%J found in the comparison areas above 59th Street. Neither cristobalite nor tridymite was detected in any of the settled surface dust samples. Similarly gypsum was found at a maximum estimated concentration of 30%J in settled surface dust, higher than the 4%J estimated in the comparison areas above 59th Street. Calcite and portlandite had maximum concentrations of 21%J and 8%J respectively. At lower Manhattan locations sampled, quartz was detected in 81% of common areas and 53% of residences. Gypsum was seen in 88% of common areas and 79% of residences. Minerals were

found in all lower Manhattan outdoor settled surface dust samples at estimated values ranging as high as 27%J quartz, 19%J calcite, 5.5%J portlandite, and 27%J gypsum. No visible settled outdoor dust was available in the comparison areas above 59th Street.

The NYCDOHMH/ATSDR investigators caution that the results of the NYCDOHMH/ATSDR investigation in Manhattan cannot be extrapolated to the lower Manhattan dwellings due to the limited number of units sampled and limited ability to address different cleaning methods, distance from ground zero, or other confounding factors.

Some of the key conclusions of the NYCDOHMH/ATSDR final report are:

· Exposure to significant amounts of SVF, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum) may cause skin rashes, eye irritation, and upper respiratory irritation, all of which have been voiced as concerns by citizens and first responders. These irritant effects will subside once exposure to SVF, mineral components of concrete, and mineral components of building wallboard end. Some people with pre-existing heart or lung disease (e.g., asthma) or a previous history of very high levels of exposures (occupational) to SVF, mineral components of concrete, and mineral components may be more sensitive to the irritant effects of SVF, mineral components of concrete, and mineral components of building wallboard.

· Sometimes mineral components of concrete (calcite and portlandite) and mineral components of building wallboard (gypsum, mica, and halite) were detected in air samples at higher estimated levels in lower Manhattan residential areas than in samples taken at comparison residential areas. These detected mineral levels are orders of magnitude below occupational standards. Although the occupational standards do not account for sensitive individuals or extended periods of exposure, they provide a comparison to an established health guidance value. The levels of minerals seen in airborne dust do not pose potential health hazards even for a continuous year of exposure at the highest levels detected.

· Some settled surface dust could become airborne if disturbed. Therefore, people could potentially inhale the asbestos, SVF, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) found in settled surface dust of some lower Manhattan residences. Because the weight of dust present in the areas sampled was not determined, it is not possible to determine whether any particular residence had an elevated dust loading. Appropriate continued frequent cleaning should minimize exposures.

· Several worst-case assumptions were made in order to assess the potential long-term public health risks of airborne asbestos and quartz. Some of the assumptions were that no cleaning of indoor spaces has occurred or will occur, all fibers found in air were asbestos fibers, and the highest levels detected last fall in air represent long-term air levels. Using these worst-case assumptions, prolonged exposure (decades) to airborne asbestos and quartz *may* increase the long-term, theoretical risk of people developing lung cancer and

other adverse lung health effects (more than 1 additional case in 10,000 people exposed). For individuals who conduct frequent cleaning of their residences, or participate in the EPA cleaning/sampling program (described below), it is unlikely that their exposure would resemble these worst-case conditions. Residents who follow these cleaning recommendations would not be expected to have any significant increased risk of cancer or other long-term health effects due to asbestos or quartz.

Based upon the conclusions of their investigation, NYCDOHMH and ATSDR made the following recommendations (NYCDOHMH/ATSDR, 2002):

· Because more asbestos, synthetic vitreous fibers (e.g., fiberglass), mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite) were found in settled surface dust in lower Manhattan residential areas when compared to comparison residential areas, the New York City Department of Health and Mental Hygiene and the Agency for Toxic Substances and Disease Registry are recommending that people continue to conduct frequent cleaning with HEPA vacuums and damp cloths/mops to reduce the potential for exposure.

· To ensure that the recommended frequent cleaning is effective and to ensure that the health of the people of New York City is protected, the New York City Department of Health and Mental Hygiene and the Agency for Toxic Substances and Disease Registry are recommending additional monitoring of residential areas in lower Manhattan. In addition, an investigation should be conducted to better define background levels specific to the city of New York for asbestos, synthetic vitreous fibers, mineral components of concrete (quartz, calcite, and portlandite), and mineral components of building wallboard (gypsum, mica, and halite).

· Lower Manhattan residents concerned about possible World Trade Center-related dust in their residential areas can request cleaning and/or testing from the Environmental Protection Agency as part of their current clean-up program (see next section).

VI.b.2. The Multi-Agency Task Force Efforts Led by US EPA

EPA and its federal, state and city partners have begun to clean up residences impacted by the collapse of the World Trade Center. The clean-up covers residential units south and west of Canal, Allen and Pike Streets, river to river. This effort is being coordinated by the multi-agency Task Force on Indoor Air in Lower Manhattan created by the EPA Administrator. Much of the information on this clean up effort can be found on the web at http://www.epa.gov/wtc. The clean-up includes:

- upon request, the clean-up of residential units, using certified contractors, with followup testing for asbestos in the indoor air, or; testing-only of asbestos in the indoor air;
- reimbursement for HEPA (High Efficiency Particulate Air) filter vacuums;
- distribution of health and cleanup information;

- establishment of a Web page (http://www.epa.gov/nyrdust2/dustcleanup/) and a toll-free hotline (1-877-796-5471 (TTY for the deaf and hard of hearing: 1-800-396-1018)) to take cleanup and testing requests;
- professional cleanups of remaining unoccupied, uncleaned buildings;
- evaluation of effectiveness of dust cleanup techniques already used, and testing to establish what the pre-existing levels of contaminants were for Manhattan residences.

Three studies are underway to help develop this clean up plan:

Indoor Air Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks - The Contaminants of Potential Concern (COPC) Committee of the World Trade Center Indoor Air Task Force is preparing this report to select COPCs and set health-based benchmarks for levels in residences to assist the Pilot Cleaning Effectiveness Initiative and inform the selection of contaminants in the Background Study (these latter two studies are addressed below). Six COPCs have been proposed: lead, PAHs, dioxin, asbestos, fibrous glass and crystalline silica. For each COPC, benchmark screening levels have been established for both indoor air and indoor surfaces, using a three tier approach:

- Tier I - Level above which, after elimination of potential indoor sources (combustion by-products, stored chemicals, etc.), aggressive clean-up action should be taken expeditiously along with follow-up sampling to confirm attainment of Tier III level.
- Tier II - Range where diligent cleaning should continue, after elimination of potential indoor sources (combustion by-products, stored chemicals, etc.), with follow-up sampling to confirm attainment of Tier III level.
- Tier III - Level below which the risk is negligible or consistent with the New York City background level found in the Background Study.

Pilot Cleaning Effectiveness Initiative - EPA is conducting a pilot program in an uncleaned/unoccupied building at 110 Liberty Street to determine the effectiveness of various cleaning methods for removing asbestos and other contaminants of potential concern from residential dwellings. EPA has completed sampling for contaminants in 110 Liberty Street, a still-unoccupied building close to the WTC site, in what is a comprehensive test of the effectiveness of various cleanup techniques. Cleaning procedures to be tested include those that were recommended following the collapse of the WTC as well as others that may have been used in cleaning residential units. Comprehensive sampling has been or will be conducted before, during and after the pilot cleanup.

Background Study - Most if not all of the pollutants associated with the collapse of the World Trade Center were present in New York City's environment prior to September 11. To establish a baseline for the presence of these contaminants in affected residences, EPA will collect and analyze samples to look for some of these pollutants in apartments in parts of Manhattan that were not impacted. The Agency will use the data to determine pre-existing or "background" levels of these pollutants in interior spaces in New York City.

VI.b.3. Ground Zero Elected Officials Task Force Study of Apartments

A "Ground Zero" Elected Officials Task Force convened within days of September 11 to evaluate the environmental safety of apartments that housed an approximate population of 50,000 residents of lower Manhattan who lived within blocks of Ground Zero. A small-scale monitoring study of two residential buildings was conducted by contract (Chatfield and Kominsky, 2001). Surface wipe samples were taken from both exposure residential dwellings characterized as "high" and "low". The "high" location, so named due to the expectation that higher concentrations would be measured, was in an apartment building located on South End Avenue, close to and southwest of Ground Zero. Apartment 10D, on the East side of this building and which had sustained window damage, was selected for sampling. Heavy dust deposits were in the apartment and were sampled for this study. The "low" location was located four blocks north on Warren Street. The apartment building did not appear to sustain any external damage. Apartments on the 2nd and 5th floor were sampled. Dioxins, furans, and PCBs were measured in wipe and bulk dust samples. Inorganic metals including arsenic, cadmium, mercury, lead, and several others, were measured. Asbestos in air and dust was also measured in all sites.

Concentrations of dioxin, PCBs and metals were generally within "background" levels for both the "high" and "low" exposure apartments. However, asbestos readings were elevated in both air and dust, particularly in the "high" apartment. Chrysolite asbestos fiber counts were obtained using TEM analysis and AHERA counting protocols (fibers > .5 μm) and also by PCME (fibers >5 μm). Looking at the TEM analysis using AHERA protocols for this summary, 7 air samples in the "low" site showed 6 indoor exceedences of the 70 S/mm^2 AHERA standard at 316, 379, 279, 142, 141, and 162, with the last sample being a rooftop sample showing a reading of 6.5 S/mm^2. All these samples were obtained at volumes very near the required 1200 liters. The "high" air samples were extremely elevated with asbestos, and most samplers were discontinued before 1200 liters due to high dust on the filter. Counting of structures greater than 0.5 μm was stopped after just one grid opening because of the large number of structures to count. The six measurements equal 10,620; 7,832; 6,277; 6.285; 7,155; and 548 S/mm^2. The last sample listed here was an exterior sample; it was taken from just outside a sliding window in the apartment.

Asbestos in indoor dust samples was similarly very high. At the "low" apartment, dust was visible on all surfaces and wipe samples were taken with a wet non-woven cloth in accordance with ASTM D6480-99. At the "high" apartment, furniture and surfaces were coated with a thick coat of dust that could be swept up with a brush. A new toothbrush was used to collect samples in this apartment. At the low apartment, surface chrysotile concentrations up to 470,000 S/cm^2 were observed, of which up to 79,000 fibers/cm^2 were fibers and bundles longer than 5 μm. In the high apartment, surface chrysotile concentrations of up to 990,000 S/cm^2 were observed, of which up to 46,000 were fibers and bundles longer than 5 μm.

Outdoor dust samples and the percentage chrysotile by weight included: a sample collected on the roof of an automobile parked on Church St on the North side of the WTC site - 0.67% chrysotile, on top of an apartment house on Warren St - 1.05% chrysotile, and two samples on the southwest side of the WTC site on South End Ave - 2.25% and 2.05% chrysotile.

VI.b.4. New York City Department of Environmental Protection Sampling of Indoor Dust and Air

The New York City Department of Environmental Protection (NYCDEP) has gathered indoor dust and air sampling data from numerous building owners/managers as part of their Asbestos Control Program. Sampling procedures and analytical methods vary from building to building making data summary difficult. For settled dust, bulk samples were generally obtained and analyzed for percent asbestos content. Many buildings report pending results. Available data indicate non-detect or trace amounts of asbestos in most locations. In general, asbestos concentrations were low especially when compared with occupational standards. Most sample analyzed by PCM (NIOSH 7400) were below 0.01 f/cc while most samples analyzed by TEM (AHERA) were below 70 S/mm^2.

VI.b.5. New York City Board of Education Sampling of Schools

At the request of the Board of Education (BOE), ATC Inc. conducted bulk dust/wipe and indoor air sampling during the time period December 2001 to March 2002 in the following WTC area schools: Stuyvesant HS (345 Chambers St), HS of Economics and Finance (100 Trinity Place), HS for Leadership and Public Service (90 Trinity Place), PS 150 (334 Greenwich St), PS 234 (292 Greenwich St), and PS/IS 189 (201 Warren St). A limited amount of asbestos bulk dust samples were obtained from these schools. No samples taken from inside the schools exceed 1% asbestos. One sample from PS/IS 189 taken from outside the building exceed 1% asbestos and one sample taken from debris on the roof of PS 234 exceeded 1% asbestos. Wipe samples were obtained and analyzed for a host of contaminants including lead, chromium, cyanide, PCBs, dioxin, silica and fibrous glass. With few exceptions, levels were below health-based guidelines/standards. Exceptions included: P S 150 had one lead sample from a window well that exceeded HUD guidelines; HS of Economics and Finance had multiple lead wipes that exceeded HUD guidelines; Stuyvesant HS had lead samples from the 5th and 6th floor that exceeded 40 µg/ft^2 on 02/06/02, but follow-up sampling the next day were below HUD guidelines.

All six schools were repeatedly sampled (samples from Stuyvesant began on 9/21/01) for asbestos in air by AHERA TEM protocols. All samples were below the AHERA standard of 70 S/mm^2 with the following exceptions: HS for Leadership and Public Service - (2/23/02) 956 S/mm^2 found in the 2nd floor auditorium; (2/24/02) 2,379 S/mm^2 found in the basement gym; (2/26/02) 978 S/mm^2 found in the basement gym. Two follow-up samples taken from the gym on 2/28/02 were non detect.

All six schools were repeatedly sampled for respirable particulates ($PM_{2.5}$). Most schools had multiple days that exceeded the 24 hr standard for sensitive subpopulations (40 µg/m^3) but few exceeded the 24 hour standard of 65 µg/m^3.

Section VII. Comments and Future Studies

Ambient concentrations of monitored substances of concern have generally decreased to background concentrations in the aftermath of the September 11 disaster. Most substances were at these backgrounds during 2002, although some exceptions were noted. Concentrations of benzene and other VOCs at the North Tower site were considerably above typical urban background as recently as early January, and air concentrations of dioxin were considerably elevated above urban background at monitors close to the WTC site through early December. The average daily benzene concentration at the North Tower was also above the OSHA PEL in early January. Concentrations of asbestos above the AHERA standard were detected in February and March.

Although the general trend of decreasing ambient concentrations for the measured pollutants is reassuring, there are limitations in the interpretation of the data. For example, very little data are available for exposures in the few days to a week immediately after September 11, and there is very little information on exposures inside residences or offices where people spend most of their time. Sampling of air and dust within residences has been conducted by ATSDR, and the results of that study are provided. This study showed very little asbestos in the air in apartments near the WTC and in the comparison apartments. However, a small number of apartments near the WTC had asbetsos detected in the dust samples while none were detected in the comparison apartments. Air and dust within 2 apartments located near the WTC were sampled on September 18. Very low concentrations of dioxin, PCBs and metals were found. However, asbestos readings were elevated in both air and dust in both apartments. EPA is now conducting extensive indoor air monitoring, and the results will be evaluated in future EPA reports.

Data do exist for reactive VOCs such as formaldehyde, acetaldehyde, or acrolein, all of which are irritants and might have been produced by the fires at WTC, but to date, these data have not been evaluated. Although the press reported the fires to be out at the WTC site on December 20, there are reports that the fires flared up on occasion in January.

From interpretation of photographs taken during the hours following the collapse of the WTC Towers, it is speculated that some people may have been exposed to the extremely high levels of ambient PM and its constituents were likely to be at risk for immediate acute respiratory and other symptoms. Fine particles or metals such as chromium and nickel in the initial dust cloud could have been irritating or sensitized individuals to further response. The cumulative risk from so many different exposures at high concentrations may well have produced effects that cannot be fully discerned by examination of exposure to individual substances. The potential for multiple chemical sensitivities is of potential concern. Also, even though data may suggest that a substance is associated with a particular effect, a quantitative guidance value may not have been developed. Thus, simply comparing ambient concentrations against known health guidance values may overlook some effects.

Further studies of potential health effects resulting from the WTC disaster are being conducted by a variety of agencies and institutions. These should help in evaluating some of the remaining uncertainties regarding exposure and human health impacts resulting from the

collapse of the WTC buildings. Results from some of these studies are not expected for several years, although some results should be available earlier. Studies are being conducted to evaluate exposures and health effects in persons that were around Ground Zero on September 11 and throughout the rescue and cleanup operations. The studies will be extremely important in getting a more complete picture of some of the actual health effects that resulted from exposures. This is particularly important because we have very little data regarding what people were exposed to September 11 as they were leaving the WTC area surrounded by plumes of dust and burning debris.

To better understand actual exposures on September 11, researchers at EPA's ORD laboratories, in cooperation with academic institutions, are working on projects that will use computer models to reconstruct the plume of dust and debris. The goal is to model and predict the levels of contaminants that were present in the air immediately following the collapse of the WTC buildings. Preliminary results from that modeling have been presented in this report. Investigators are using meteorological data and data available from monitoring results later in September to estimate exposures. When this research is complete, it will aid in addressing health effects.

Studies are also being conducted to help us better understand how exposure to contaminants measured and collected in lower Manhattan throughout this period may cause adverse effects in laboratory tests and animal models. As cited previously, ORD NHEERL scientists conducted several studies to examine the chemical and toxicological properties of $PM_{2.5}$ derived from bulk settled WTC dust (EPA, 2002c; McGee et al., 2002). Comparative respiratory toxicology studies showed that a high dose of WTC $PM_{2.5}$ caused mild lung inflammation and significant respiratory tract hyperresponsiveness in mice. Ambient concentrations which could cause comparable doses and effects in people are high but conceivable (425 $\mu g/m^3$ over 8 hours) in the immediate aftermath of the collapse of the towers (Gavett et al., 2002). Dust and air samples are also being evaluated by other researchers through funding from NYSDOH.

Most importantly, many local, state and federal agencies and academic institutions have already began or are planning studies that will monitor the health status of various groups of people that were affected by the events of September 11. In total, EPA is aware of more that 120 studies on health effects in populations impacted by the events of September 11. Although it is impossible to address them all, a few general categories are discussed below.

- Health status, including asthma, among students is one of the many health endpoints that will be evaluated at many schools. Respiratory symptoms, including asthma, will be studied in pre-school children and other child populations as well.

- Longitudinal cohort studies on the impacts on pregnant women and birth outcomes are also being conducted.